US009048770B2

(12) United States Patent
Tamai et al.

(10) Patent No.: US 9,048,770 B2
(45) Date of Patent: Jun. 2, 2015

(54) **SYNCHRONOUS MACHINE STARTING DEVICE**

(75) Inventors: **Shinzo Tamai**, Minato-ku (JP); **Hisanori Taguchi**, Minato-ku (JP); **Yasuhiko Hosokawa**, Minato-ku (JP); **Akinobu Ando**, Minato-ku (JP)

(73) Assignee: **TOSHIBA MITSUBISHI-ELECTRIC INDUSTRIAL SYSTEMS CORPORATION**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 251 days.

(21) Appl. No.: **13/878,836**

(22) PCT Filed: **Oct. 15, 2010**

(86) PCT No.: **PCT/JP2010/068178**

§ 371 (c)(1),
(2), (4) Date: **Apr. 11, 2013**

(87) PCT Pub. No.: **WO2012/049770**

PCT Pub. Date: **Apr. 19, 2012**

(65) **Prior Publication Data**

US 2013/0193884 A1 Aug. 1, 2013

(51) **Int. Cl.**
H02P 1/46 (2006.01)
H02P 6/20 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC .. ***H02P 6/20*** (2013.01); ***H02P 1/46*** (2013.01); ***H02P 21/0032*** (2013.01); ***H02P 21/146*** (2013.01); ***H02P 21/0039*** (2013.01)

(58) **Field of Classification Search**
CPC H02P 1/46; H02P 1/146; H02P 1/14; H02P 6/10
USPC 318/700, 400.02, 400.32, 400.35, 727, 318/798, 799
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,462,492 B1 * 10/2002 Sakamoto et al. 318/400.32
6,894,450 B2 * 5/2005 Cheng et al. 318/400.09
(Continued)

FOREIGN PATENT DOCUMENTS

JP 2 211079 8/1990
JP 2006 271038 10/2006
(Continued)

OTHER PUBLICATIONS

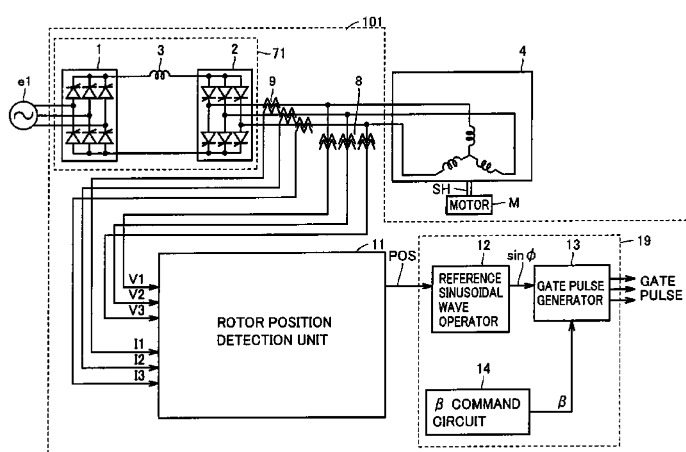
International Search Report Issued Nov. 16, 2010 in PCT/JP10/68178 Filed Oct. 15, 2010.

Primary Examiner — Rina Duda
(74) *Attorney, Agent, or Firm* — Oblon, McClelland, Maier & Neustadt, L.L.P.

(57) **ABSTRACT**

In a synchronous machine starting device, a timing detection unit outputs a first position signal indicating a timing at which a value of an armature voltage passes a prescribed reference level. A feedback operation unit calculates an error of an estimated phase based on the estimated phase, an estimated rotational speed of a rotor, an armature voltage, and an armature current, updates the estimated phase and the estimated rotational speed based on the calculated phase error, and outputs a second position signal indicating the updated estimated phase. A frequency detection unit detects a current rotational speed of the rotor based on the first position signal, as an initial value of the estimated rotational speed. A selector circuit selects the first position signal and the second position signal in this order, and outputs a selected position signal to the power conversion control unit.

20 Claims, 17 Drawing Sheets



(51) **Int. Cl.**

H02P 21/00	(2006.01)
H02P 21/14	(2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,180,263	B2 *	2/2007	Maeda et al.	318/719
7,348,749	B2 *	3/2008	Ide et al.	318/599
8,362,730	B2	1/2013	Tamai et al.	
2003/0030404	A1 *	2/2003	Iwaji et al.	318/700
2008/0061728	A1 *	3/2008	Tomigashi	318/768
2011/0181220	A1	7/2011	Tamai et al.	
2011/0254491	A1	10/2011	Tamai et al.	
2012/0161688	A1	6/2012	Tamai et al.	

FOREIGN PATENT DOCUMENTS

JP	2007 37274	2/2007
WO	2010 038282	4/2010

* cited by examiner

FIG.1

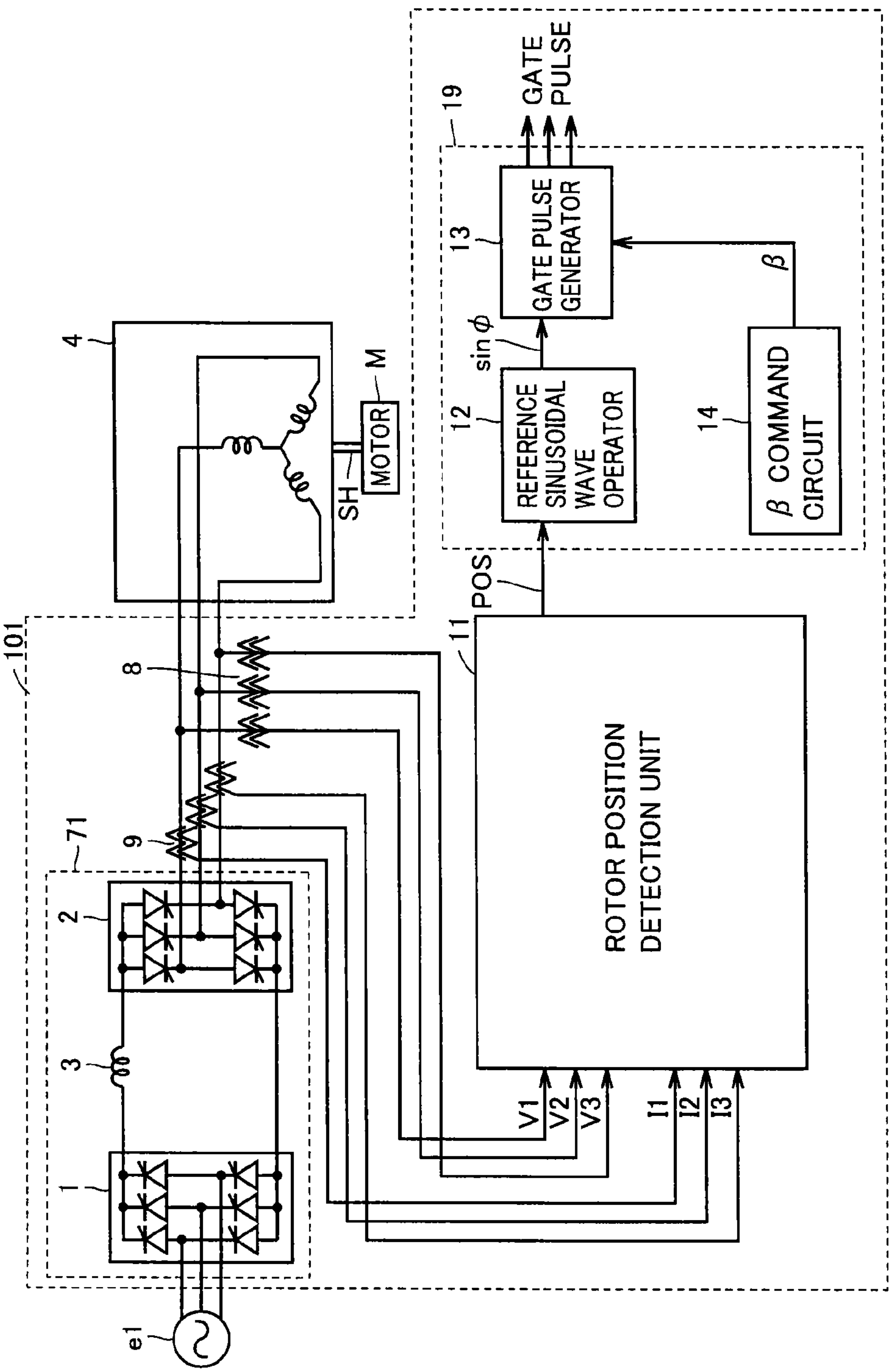

GATE PULSE
19
13
GATE PULSE GENERATOR
β
sin φ
12
REFERENCE SINUSOIDAL WAVE OPERATOR
14
β COMMAND CIRCUIT
4
M
MOTOR
SH
POS
101
11
8
ROTOR POSITION DETECTION UNIT
9
71
2
3
1
V1
V2
V3
I1
I2
I3
e1

FIG.2

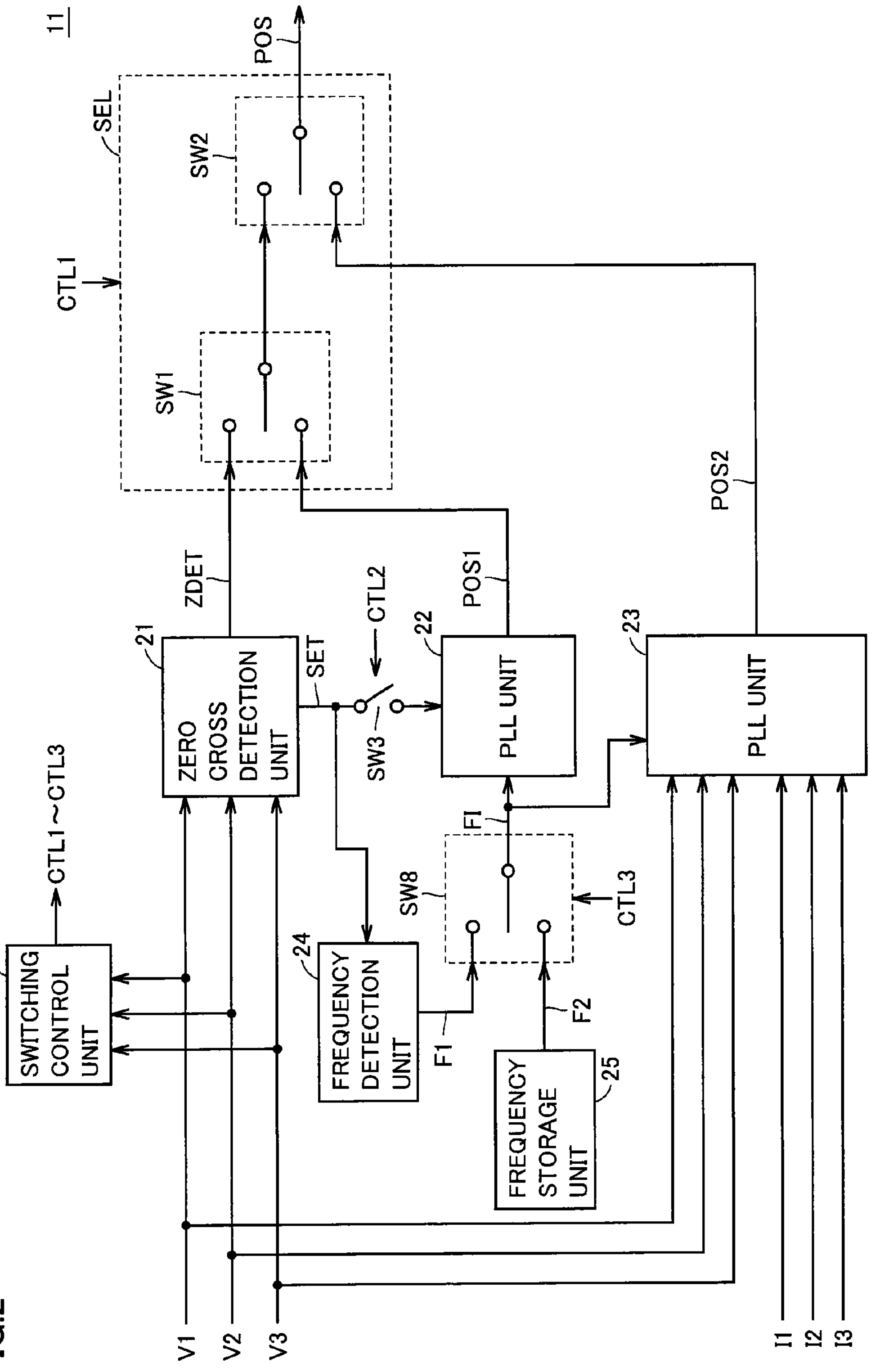

11
POS
SEL
SW2
CTL1
SW1
POS2
ZDET
POS1
CTL2
SET
21
ZERO CROSS DETECTION UNIT
22
PLL UNIT
23
PLL UNIT
SW3
CTL1~CTL3
27
SWITCHING CONTROL UNIT
24
FREQUENCY DETECTION UNIT
FI
SW8
CTL3
F1
F2
25
FREQUENCY STORAGE UNIT
V1
V2
V3
I1
I2
I3

FIG.3

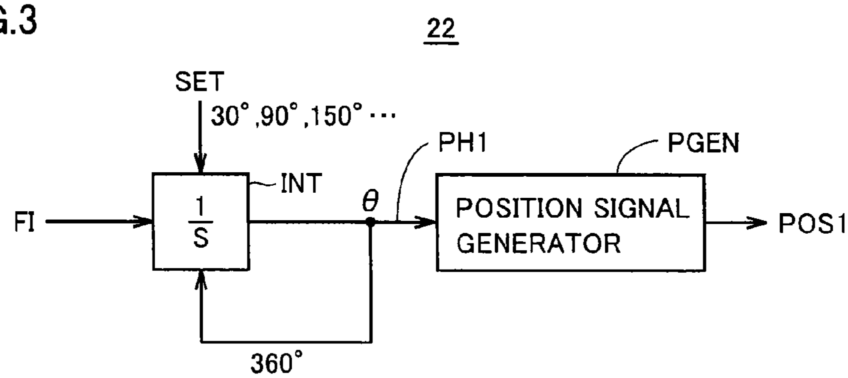


FIG.4

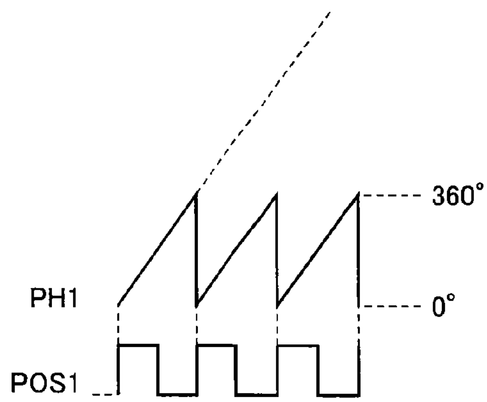


FIG.5

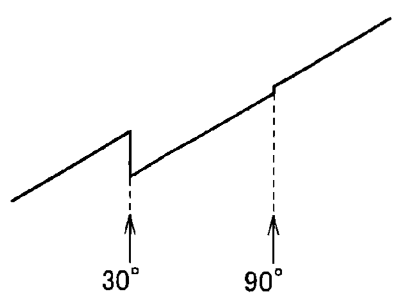
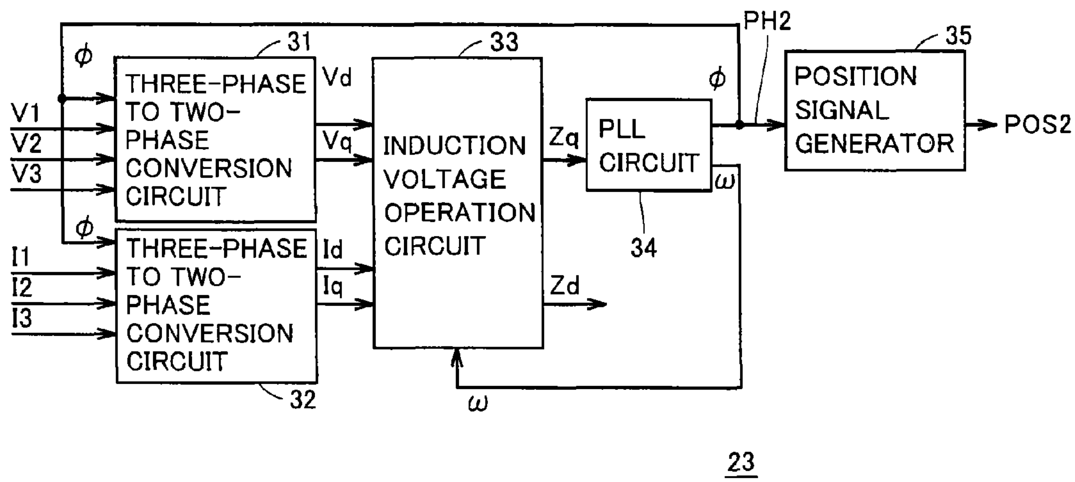
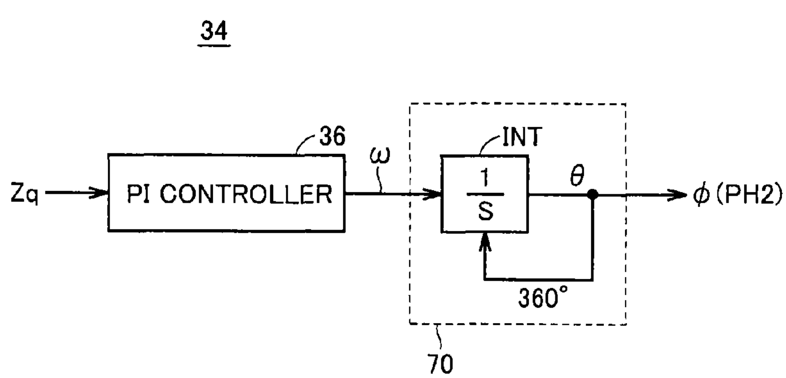


FIG.6



PH2
31
33
35
φ
THREE-PHASE TO TWO-PHASE CONVERSION CIRCUIT
Vd
φ
POSITION SIGNAL GENERATOR
V1
V2
V3
Vq
INDUCTION VOLTAGE OPERATION CIRCUIT
Zq
PLL CIRCUIT
POS2
ω
34
φ
THREE-PHASE TO TWO-PHASE CONVERSION CIRCUIT
I1
I2
I3
Id
Iq
Zd
32
ω
23

FIG.7



34
36
INT
Zq
PI CONTROLLER
ω
1/S
θ
φ (PH2)
360°
70

FIG.8

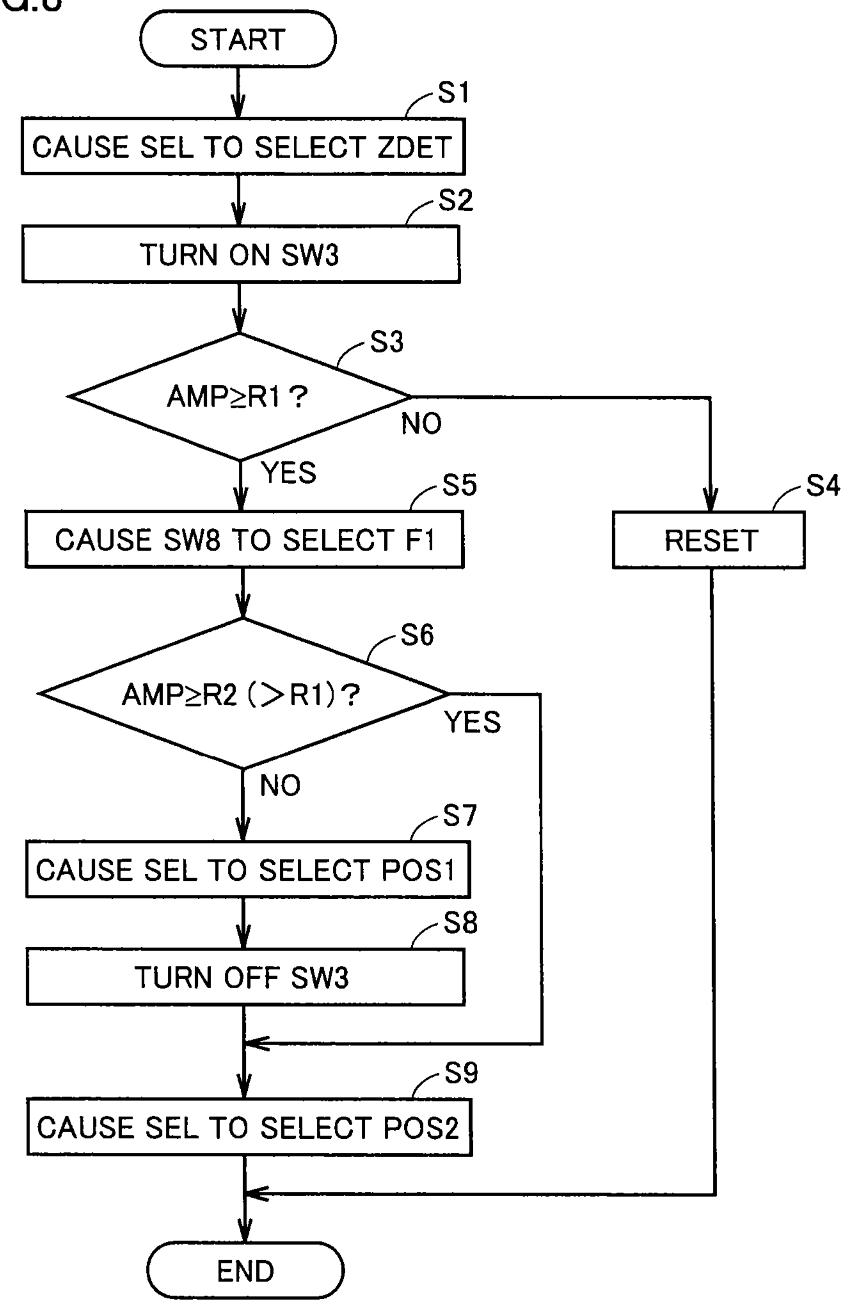

START
S1
CAUSE SEL TO SELECT ZDET
S2
TURN ON SW3
S3
AMP≥R1 ?
NO
YES
S4
RESET
S5
CAUSE SW8 TO SELECT F1
S6
AMP≥R2 (>R1) ?
YES
NO
S7
CAUSE SEL TO SELECT POS1
S8
TURN OFF SW3
S9
CAUSE SEL TO SELECT POS2
END

FIG.9

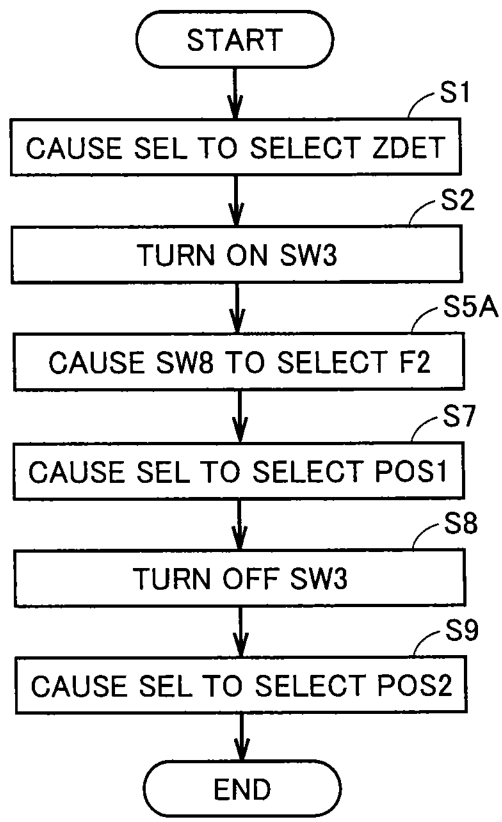

START
S1
CAUSE SEL TO SELECT ZDET
S2
TURN ON SW3
S5A
CAUSE SW8 TO SELECT F2
S7
CAUSE SEL TO SELECT POS1
S8
TURN OFF SW3
S9
CAUSE SEL TO SELECT POS2
END

FIG.10

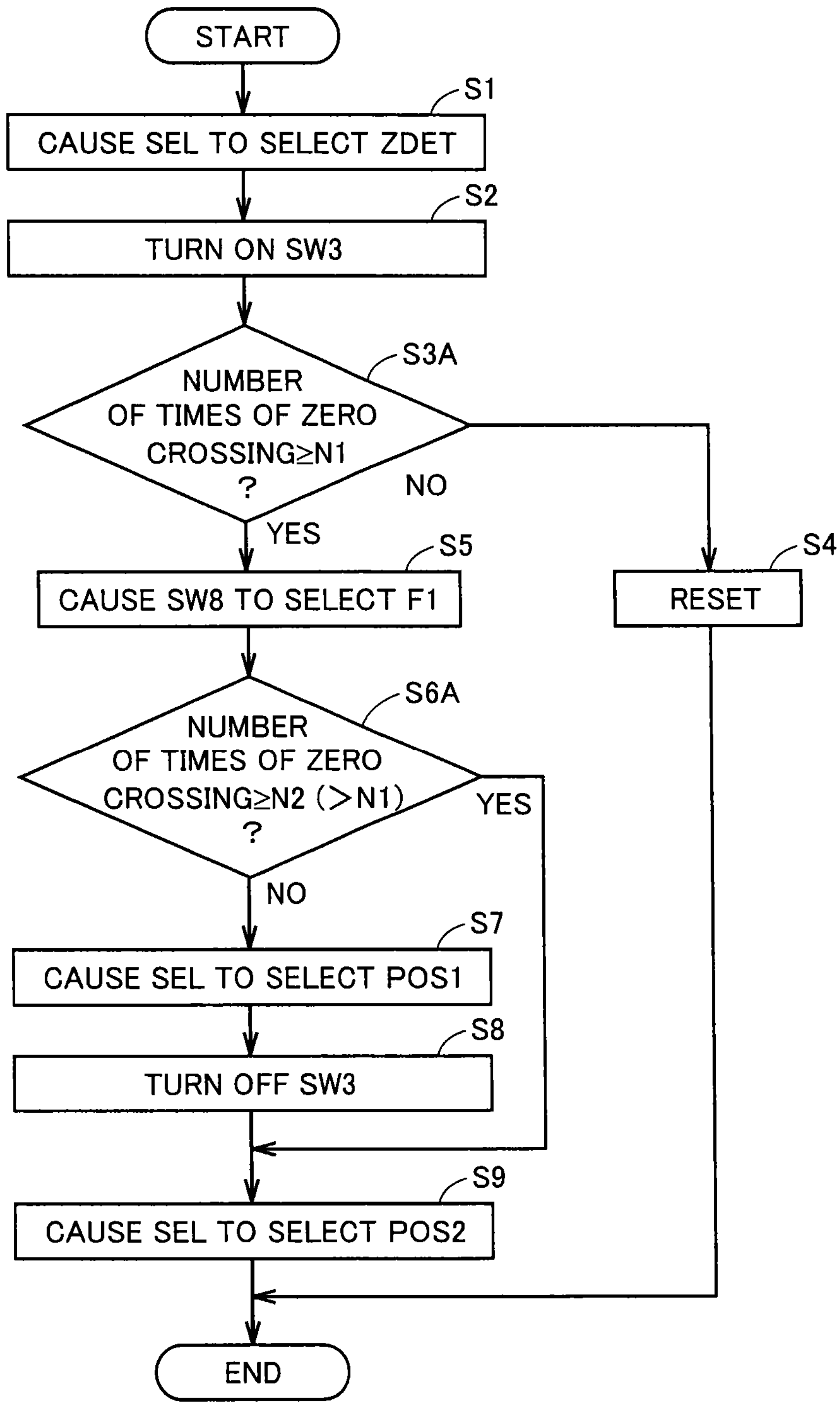

START
S1
CAUSE SEL TO SELECT ZDET
S2
TURN ON SW3
S3A
NUMBER OF TIMES OF ZERO CROSSING≥N1 ?
NO
YES
S5
CAUSE SW8 TO SELECT F1
S4
RESET
S6A
NUMBER OF TIMES OF ZERO CROSSING≥N2 (>N1) ?
YES
NO
S7
CAUSE SEL TO SELECT POS1
S8
TURN OFF SW3
S9
CAUSE SEL TO SELECT POS2
END

FIG.11

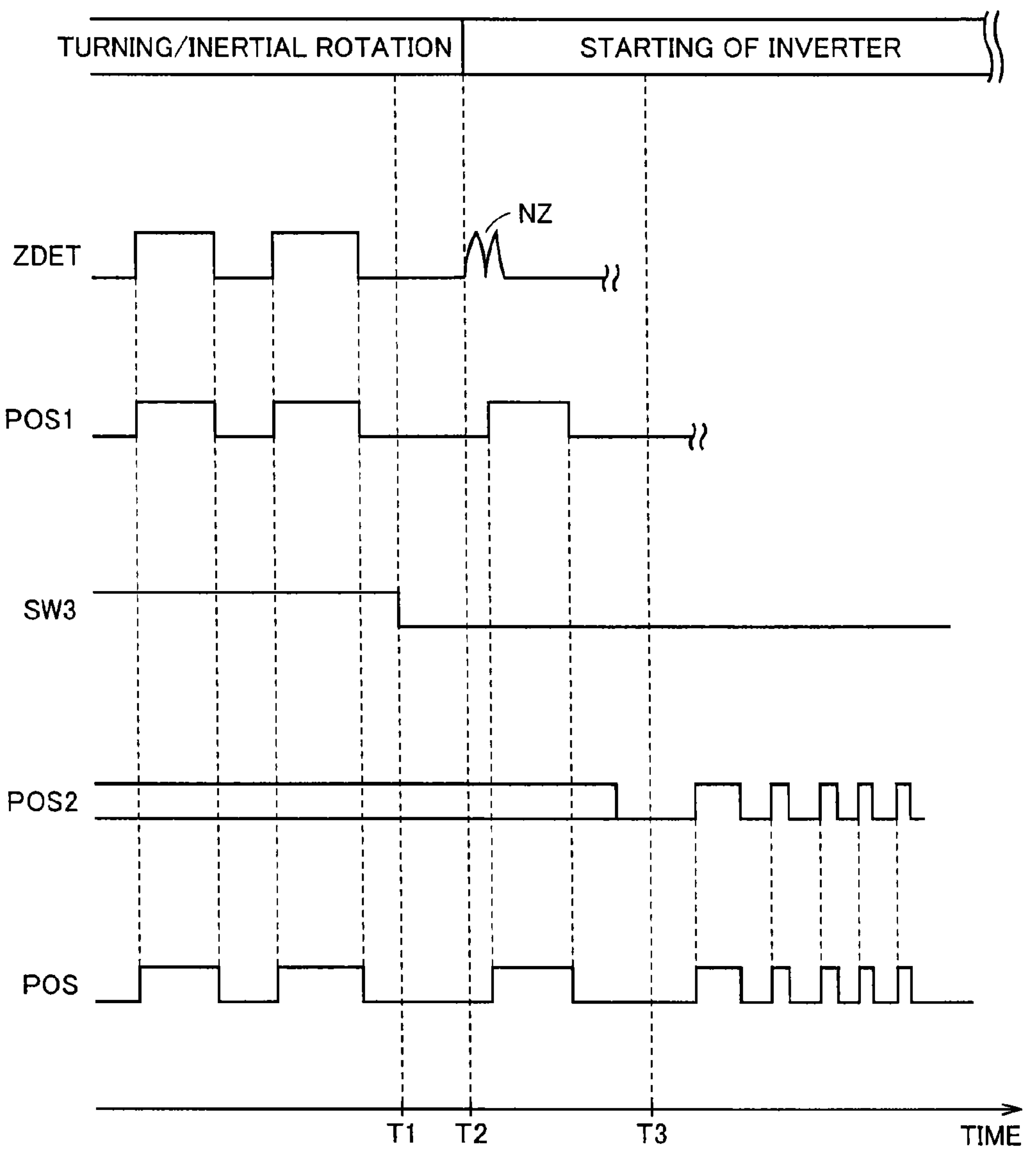
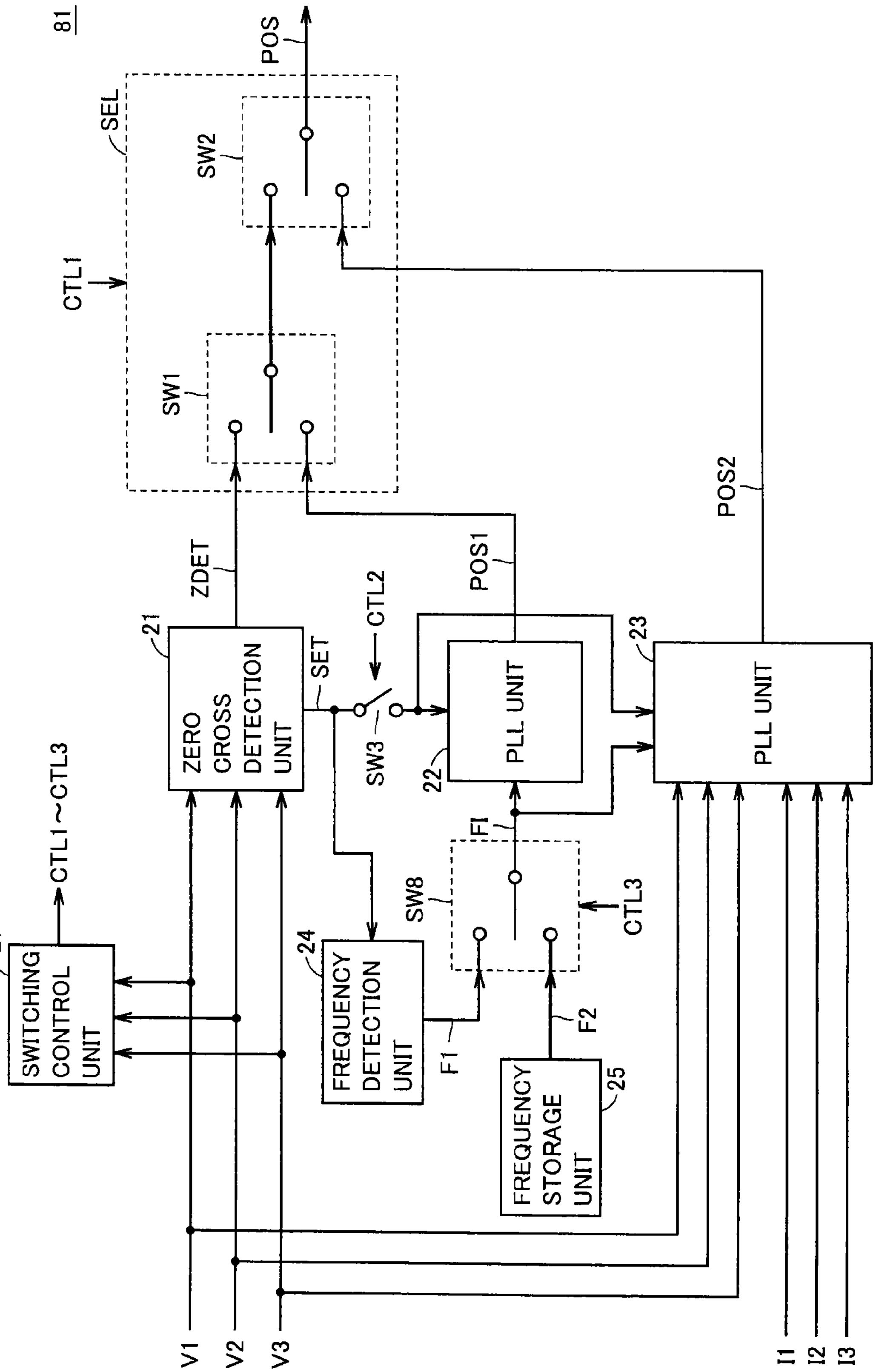

TURNING/INERTIAL ROTATION
STARTING OF INVERTER
NZ
ZDET
POS1
SW3
POS2
POS
T1
T2
T3
TIME

FIG.12



81
POS
SEL
SW2
CTL1
SW1
POS2
ZDET
POS1
CTL2
21
ZERO CROSS DETECTION UNIT
SET
SW3
PLL UNIT
22
23
PLL UNIT
CTL1~CTL3
27
SWITCHING CONTROL UNIT
24
FREQUENCY DETECTION UNIT
FI
SW8
CTL3
F1
F2
25
FREQUENCY STORAGE UNIT
V1
V2
V3
I1
I2
I3

FIG.13

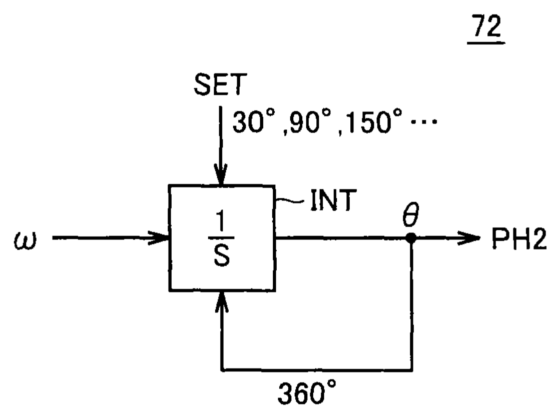


FIG.14

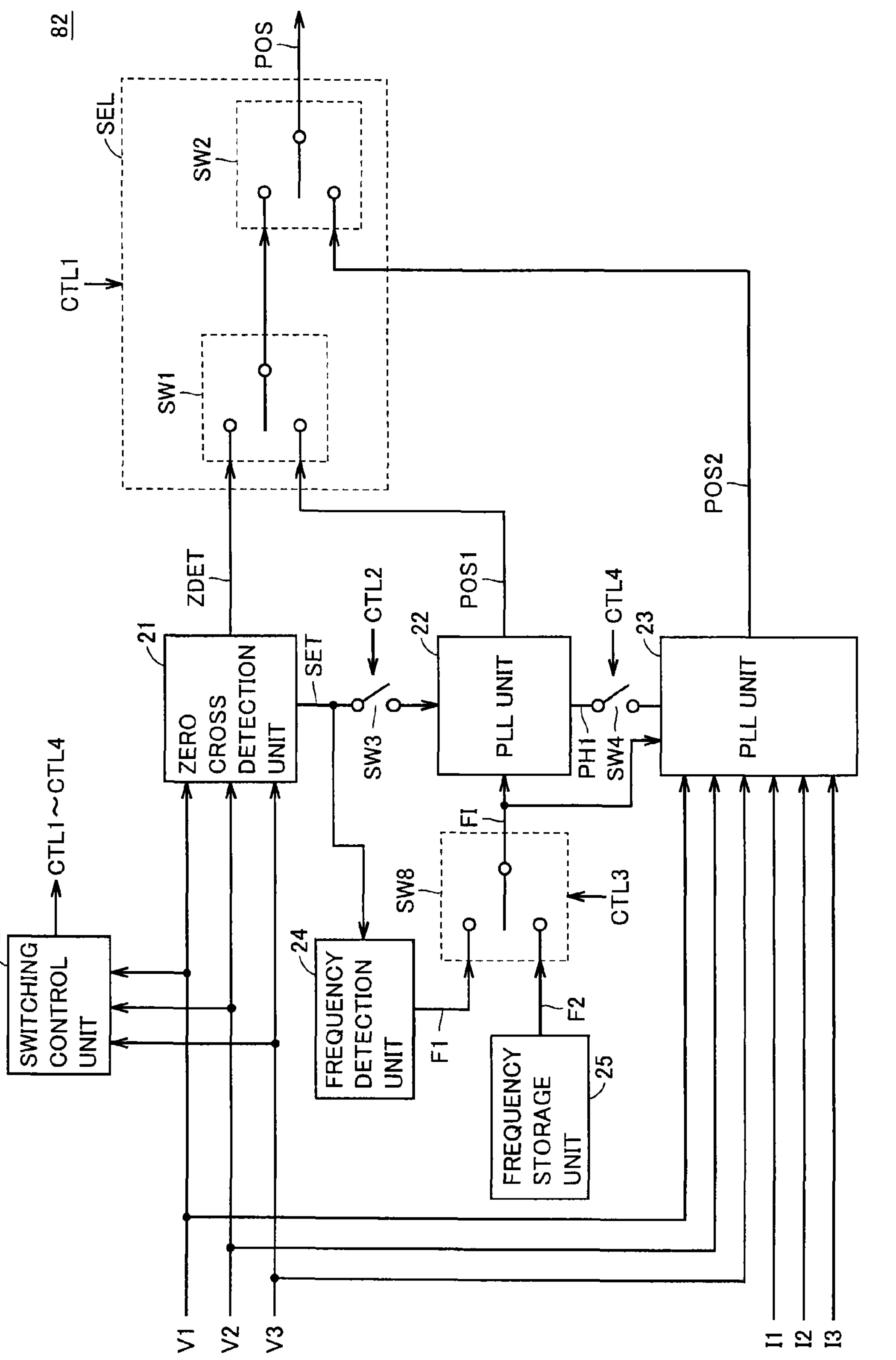

82
POS
SEL
SW2
CTL1
SW1
POS2
ZDET
POS1
CTL2
CTL4
21
22
23
ZERO CROSS DETECTION UNIT
SET
SW3
PLL UNIT
PH1
SW4
PLL UNIT
CTL1～CTL4
27
SWITCHING CONTROL UNIT
FI
SW8
CTL3
24
FREQUENCY DETECTION UNIT
F1
F2
25
FREQUENCY STORAGE UNIT
V1
V2
V3
I1
I2
I3

FIG.15

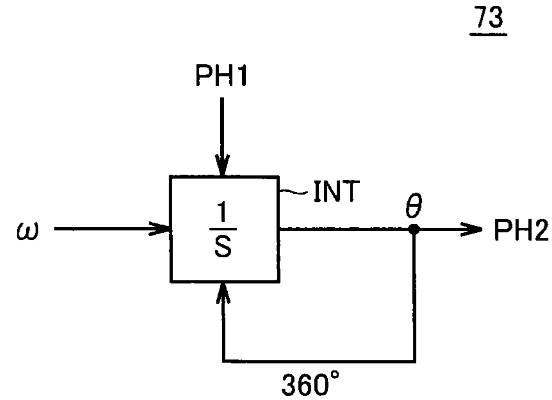

73
PH1
INT
ω
1
S
θ
PH2
360°

FIG.16

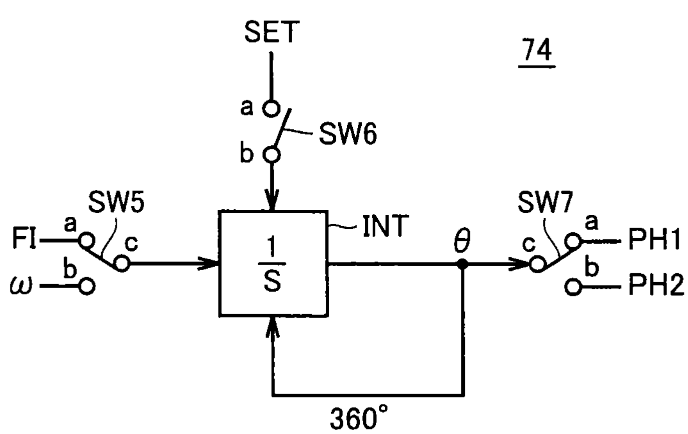

SET
74
a
SW6
b
SW5
FI
a
c
b
ω
1
S
INT
θ
SW7
c
a
PH1
b
PH2
360°

FIG.17

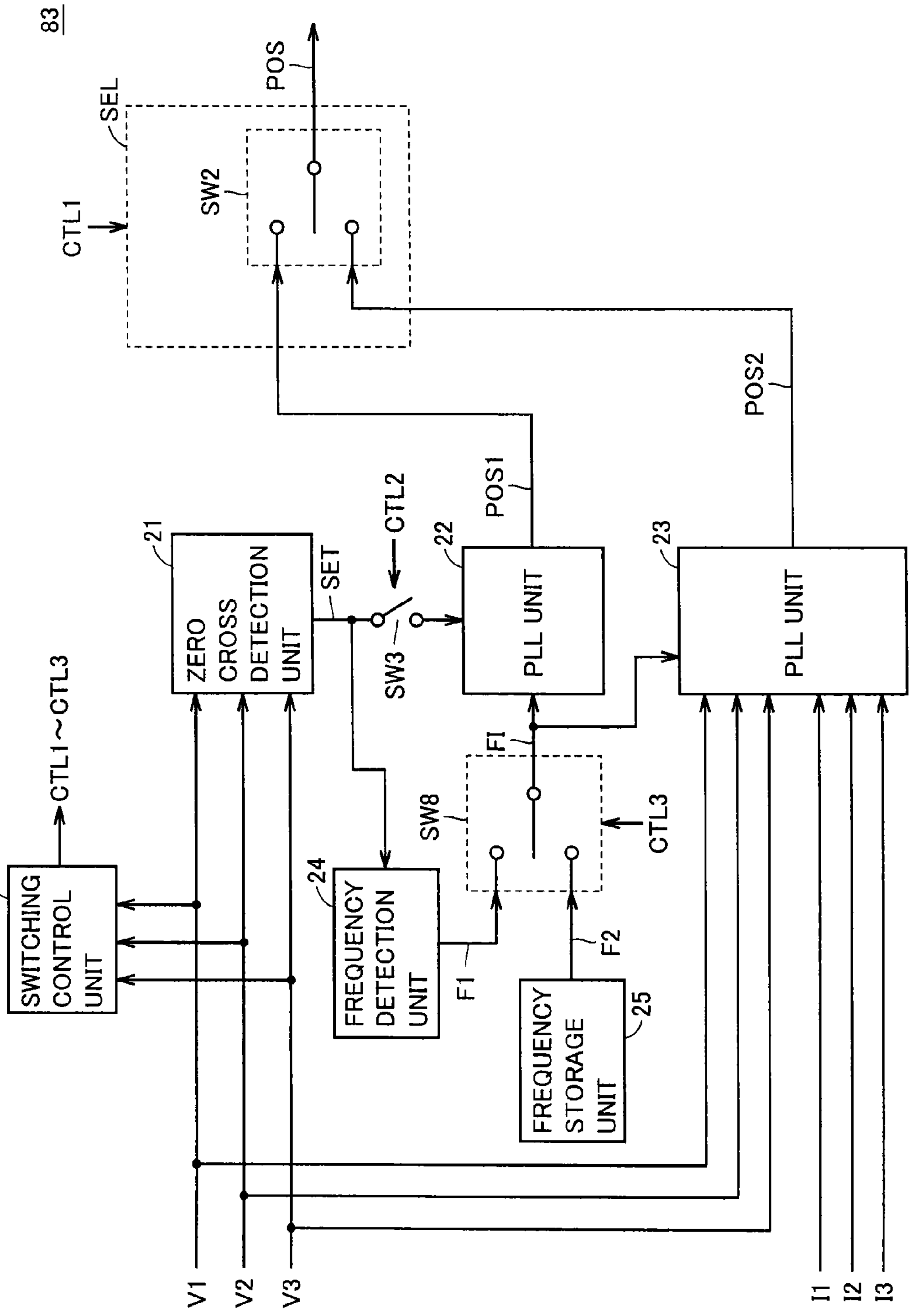

83
POS
SEL
CTL1
SW2
POS2
POS1
CTL2
21
ZERO CROSS DETECTION UNIT
SET
SW3
22
PLL UNIT
23
PLL UNIT
CTL1~CTL3
27
SWITCHING CONTROL UNIT
FI
SW8
CTL3
24
FREQUENCY DETECTION UNIT
F1
F2
FREQUENCY STORAGE UNIT
25
V1
V2
V3
I1
I2
I3

FIG.18

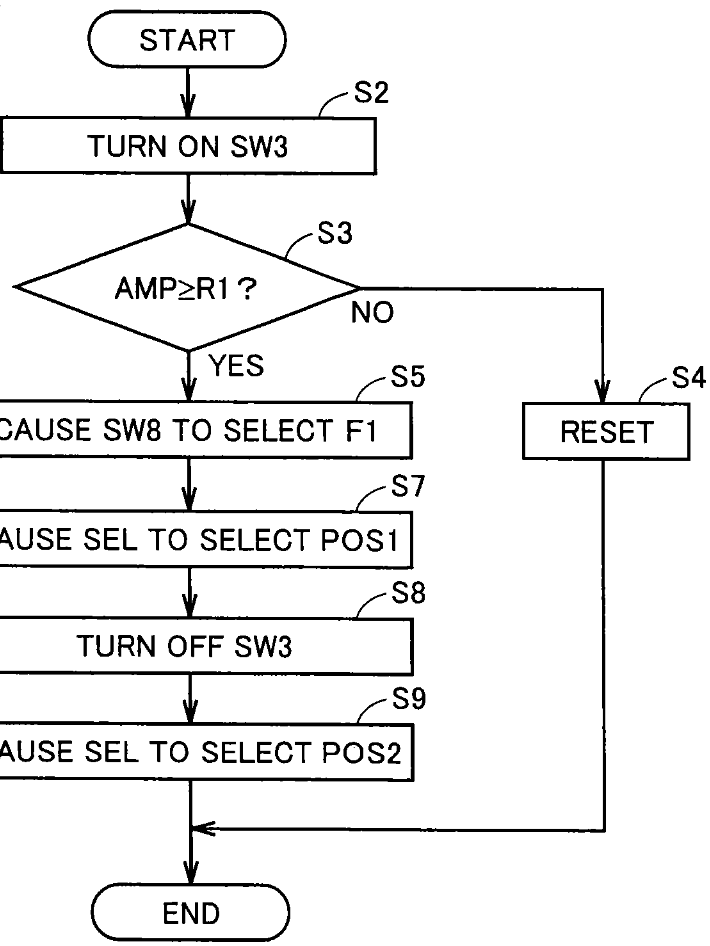

START
S2
TURN ON SW3
S3
AMP≥R1 ?
NO
YES
S5
CAUSE SW8 TO SELECT F1
S4
RESET
S7
CAUSE SEL TO SELECT POS1
S8
TURN OFF SW3
S9
CAUSE SEL TO SELECT POS2
END

FIG.19

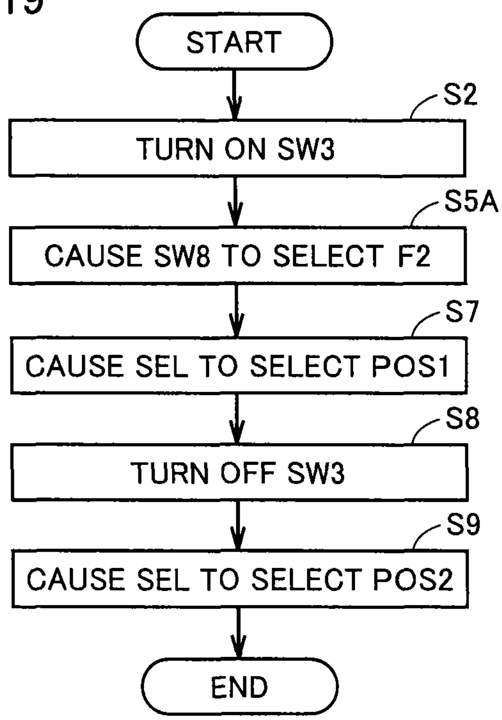
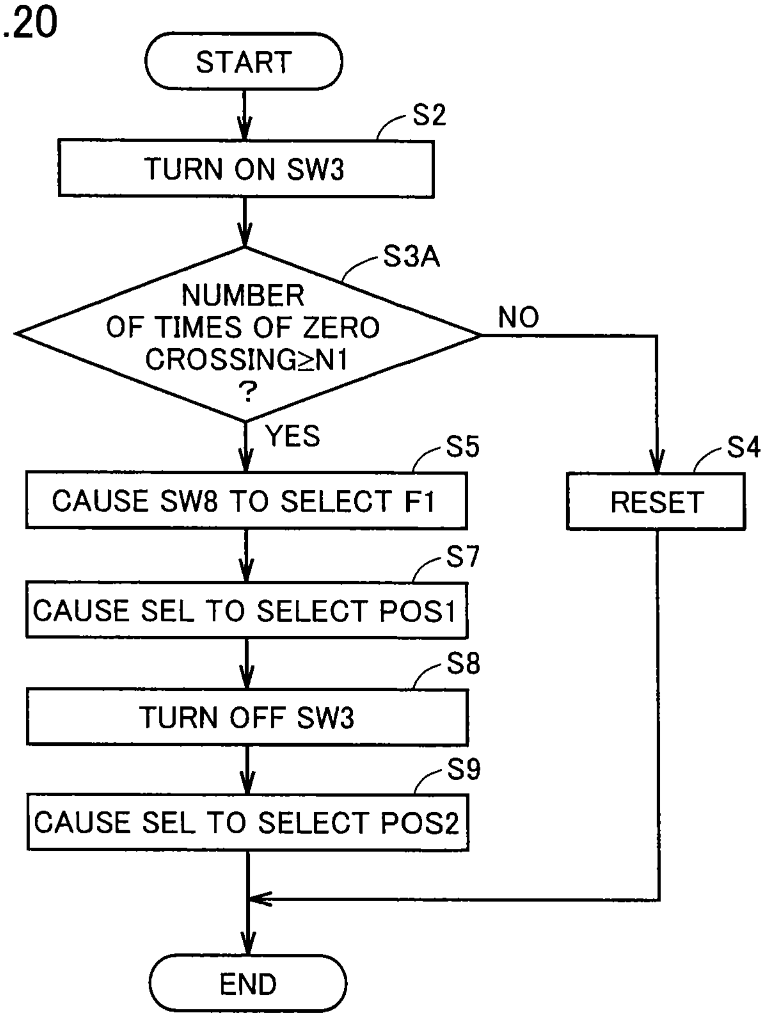
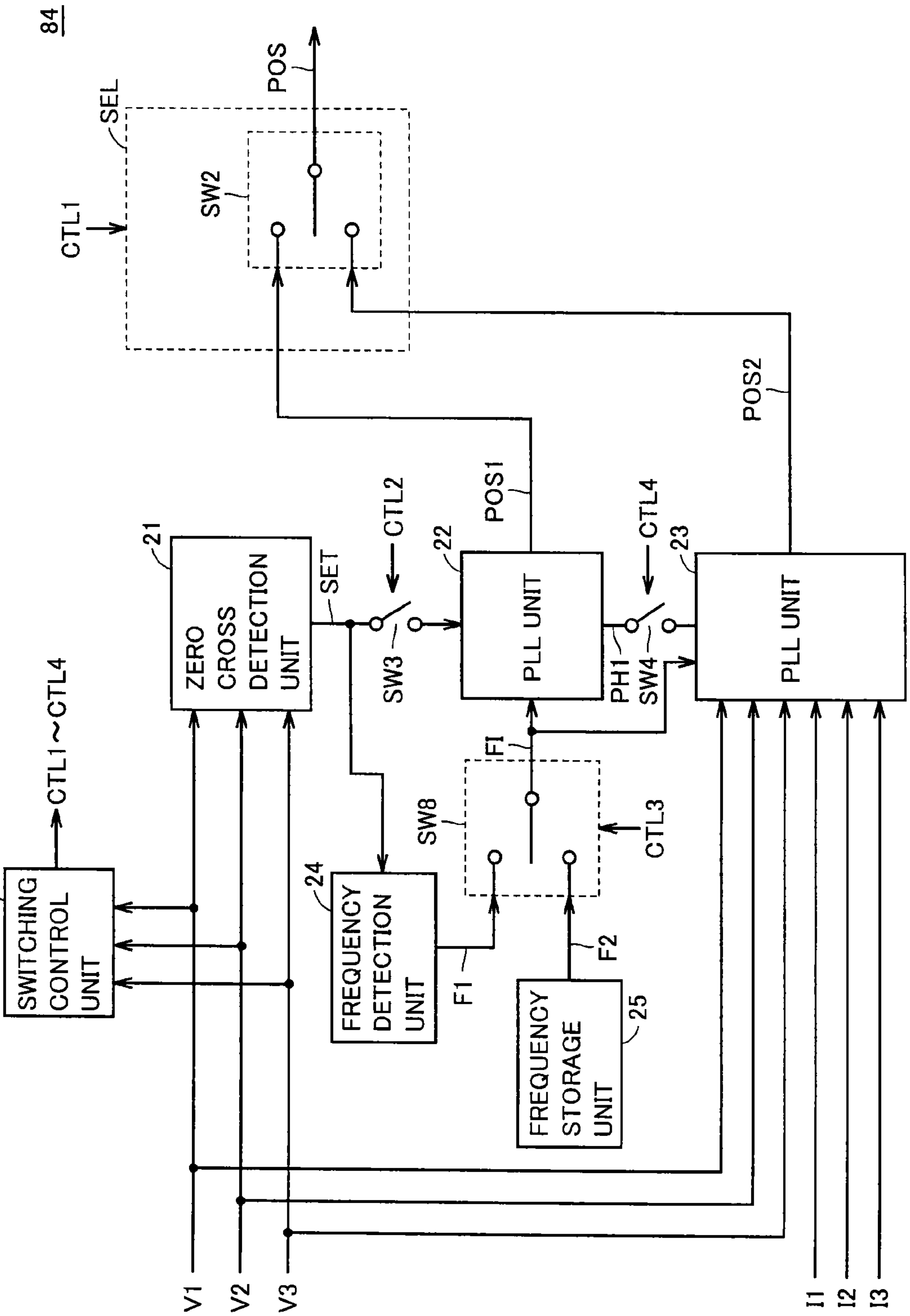

START
S2
TURN ON SW3
S5A
CAUSE SW8 TO SELECT F2
S7
CAUSE SEL TO SELECT POS1
S8
TURN OFF SW3
S9
CAUSE SEL TO SELECT POS2
END

FIG.20


START
S2
TURN ON SW3
S3A
NUMBER
OF TIMES OF ZERO
CROSSING≥N1
?
NO
YES
S5
CAUSE SW8 TO SELECT F1
S4
RESET
S7
CAUSE SEL TO SELECT POS1
S8
TURN OFF SW3
S9
CAUSE SEL TO SELECT POS2
END



84
POS
SEL
CTL1
SW2
POS2
POS1
CTL2
CTL4
21
ZERO CROSS DETECTION UNIT
SET
SW3
22
PLL UNIT
PH1
SW4
23
PLL UNIT
F1
SW8
CTL3
CTL1~CTL4
27
SWITCHING CONTROL UNIT
24
FREQUENCY DETECTION UNIT
F1
F2
25
FREQUENCY STORAGE UNIT
V1
V2
V3
I1
I2
I3

FIG.21

SYNCHRONOUS MACHINE STARTING DEVICE

TECHNICAL FIELD

The present invention relates to a synchronous machine starting device, and more particularly to a synchronous machine starting device that detects a rotor position of a synchronous machine.

BACKGROUND ART

Synchronous machine starting devices for starting synchronous machines such as generators and motors have been developed. Conventionally, a synchronous machine starting device uses a mechanical distributor that detects the position of a rotor of a synchronous machine, for example, by a proximity switch. However, the mechanical distributor is fragile and is susceptible to noise due to a large amount of wiring.

The inventors of the present application invented a synchronous machine starting device that does not require such a mechanical distributor, and filed it as an international patent application (see WO2010/038282 (PTL 1)). A synchronous machine starting device according to one embodiment described in PTL 1 will be described hereinafter.

This synchronous machine starting device includes a power conversion unit, an AC voltage detector, an AC current detector, a rotor position detection unit, and a power conversion control portion. The AC voltage detector and AC current detector detect three-phase AC voltage and three-phase AC current, respectively, supplied to or generated at an armature of a synchronous machine, and output the detection values to the rotor position detecting unit. The rotor position detection unit includes a zero cross detection unit, a first PLL (Phase Locked Loop) unit, a second PLL unit, and a selector circuit. The zero cross detection unit performs zero cross detection of AC voltage detected by the AC voltage detector. The first PLL unit outputs a position signal that is an AC signal having a prescribed frequency. Here, the prescribed frequency is a frequency corresponding to a predetermined rotational speed of the rotor during standby of the synchronous machine. The first PLL unit adjusts the phase of the position signal based on the detection signal received from the zero cross detection unit. The second PLL unit calculates an estimated phase indicating the rotor position of the synchronous machine by performing feedback operation so as to reduce an error of induction voltage of the armature, based on the detection values received from the AC voltage detector and AC current detector, and outputs a position signal obtained from the calculated estimated phase. The selector circuit selects, at the time of starting of the synchronous machine, the detection signal from the zero cross detection unit, the position signal from the first PLL unit, and the position signal from the second PLL unit in this order, and outputs the selected position signal as a rotor position signal indicating the rotor position of the synchronous machine.

CITATION LIST

Patent Literature

PTL 1: WO2010/038282

SUMMARY OF INVENTION

Technical Problem

The rated rotational speed of the synchronous machine is 3000 to 3600 rpm, for example, whereas the rotational speed

during standby is low, for example, several rpm. When the synchronous machine is stopped, the rotor of the synchronous machine continues to rotate by inertia for a while, and thus, does not immediately return to the rotational speed during standby.

Since the above-described synchronous machine starting device is aimed at stably starting the synchronous machine in the standby state, the synchronous machine cannot be restarted for a while after being stopped, and needs to be restarted after it has returned to the rotational speed in the standby state.

Accordingly, an object of the present invention is to provide a synchronous machine starting device capable of stably starting a synchronous machine not only in the standby state but also when the synchronous machine has not returned to the rotational speed in the standby state after stopping of the synchronous machine.

Solution to Problem

A synchronous machine starting device according to a first aspect of this invention includes a power conversion unit, an AC voltage detection unit, an AC current detection unit, a rotor position detection unit, and a power conversion control portion. The power conversion unit converts supplied power into AC power and supplies the AC power to an armature of a synchronous machine. The AC voltage detection unit detects AC voltage supplied to or generated at the armature of the synchronous machine. The AC current detection unit detects AC current supplied to or generated at the armature of the synchronous machine. The rotor position detection unit detects a rotor position of the synchronous machine, based on the detected AC voltage and AC current. The power conversion control portion controls the power conversion unit based on the detected rotor position. The above-described rotor position detection unit includes a timing detection unit, a feedback operation unit, a frequency detection unit, and a selector circuit. The timing detection unit outputs a first position signal indicating a timing at which a value of the detected AC voltage passes a prescribed reference level. The feedback operation unit calculates an error of an estimated phase based on the estimated phase indicating the rotor position, an estimated rotational speed of the rotor of the synchronous machine, as well as the detected AC voltage and AC current, updates the estimated phase and the estimated rotational speed based on the calculated phase error, and outputs a second position signal indicating the updated estimated phase. The frequency detection unit detects a first frequency corresponding to a rotational speed of the rotor of the synchronous machine at the time of starting of the synchronous machine starting device based on the first position signal, for use as an initial frequency corresponding to an initial value of the estimated rotational speed. The selector circuit selects the first position signal or a position signal obtained based on the first position signal, outputs the selected signal to the power conversion control portion as a signal indicating the rotor position of the synchronous machine, releases selection of the first position signal or the position signal obtained based on the first position signal, and thereafter selects the second position signal for output to the power conversion control portion as a signal indicating the rotor position of the synchronous machine.

Preferably, the rotor position detection unit further includes an initial frequency selection unit for selecting either one of the above-described first frequency and a prescribed second frequency as the initial frequency. In this case, the second frequency is a frequency corresponding to a predetermined rotational speed of the rotor during standby of the synchronous machine. The initial frequency selection unit selects the first frequency where an absolute value of the detected AC voltage is a prescribed value or higher at the time of starting of the synchronous machine starting device. The initial frequency selection unit selects the second frequency where the absolute value of the detected AC voltage does not reach the prescribed value within a prescribed time at the time of starting of the synchronous machine starting device.

Alternatively, where the initial frequency selection unit for selecting the first or second frequency is included as described above, the initial frequency selection unit selects the first frequency where the number of times that the value of the detected AC voltage passes the reference level within a prescribed time is a prescribed number or greater at the time of starting of the synchronous machine starting device. The initial frequency selection unit selects the second frequency where the number of times that the value of the detected AC voltage passes the reference level within the prescribed time is smaller than a prescribed number at the time of starting of the synchronous machine starting device.

According to a second aspect of this invention, the above-described selector circuit according to the first aspect initially selects the first position signal for output to the power conversion control portion, and then selects the second position signal for output to the power conversion control portion.

According to a third aspect of this invention, the above-described rotor position detection unit according to the first aspect further includes an AC signal generation unit for outputting a third position signal that is an AC signal having the above-described initial frequency and having a phase adjusted to be synchronized with the first position signal. In the third aspect, the selector circuit selects the first position signal, the third position signal, and the second position signal in this order, and outputs the selected signal to the power conversion control portion.

According to a fourth aspect of this invention, the above-described rotor position detection unit according to the first aspect further includes an AC signal generation unit for outputting a third position signal that is an AC signal having the above-described initial frequency and having a phase adjusted to be synchronized with the first position signal. In the fourth aspect, the selector circuit initially selects the third position signal for output to the power conversion control portion, and then selects the second position signal for output to the power conversion control portion.

According to a fifth aspect of this invention, the above-described rotor position detection unit according to the first aspect further includes an AC signal generation unit for outputting a third position signal that is an AC signal having the above-described initial frequency and having a phase adjusted to be synchronized with the first position signal. In the fifth aspect, where an absolute value of the detected AC voltage is a prescribed value or higher at the time of starting of the synchronous machine starting device, the selector circuit initially selects the first position signal for output to the power conversion control portion, and then selects the second position signal for output to the power conversion control portion. Where the absolute value of the detected AC voltage does not reach the prescribed value within a prescribed time at the time of starting of the synchronous machine starting device, the selector circuit then selects the first position signal, the third position signal, and the second position signal in this order, for output to the power conversion control portion.

According to a sixth aspect of this invention, the above-described rotor position detection unit according to the first aspect further includes an AC signal generation unit for outputting a third position signal that is an AC signal having the above-described initial frequency and having a phase adjusted to be synchronized with the first position signal. In the sixth aspect, where the number of times that the value of the detected AC voltage passes the reference level within the prescribed time is a prescribed number or greater at the time of starting of the synchronous machine starting device, the selector circuit initially selects the first position signal for output to the power conversion control portion, and then selects the second position signal for output to the power conversion control portion. Where the number of times that the value of the detected AC voltage passes the reference level within the prescribed time is smaller than the prescribed number at the time of starting of the synchronous machine starting device, the selector circuit selects the first position signal, the third position signal, and the second position signal in this order, for output to the power conversion control portion.

In each of the above-described second to fourth aspects, preferably, the selector circuit selects the second position signal when the number of times that the value of the detected AC voltage passes the reference level within a prescribed time has exceeded a prescribed number.

In each of the above-described second to fourth aspects, preferably, the selector circuit selects the second position signal when an absolute value of the detected AC voltage has reached the prescribed value or higher.

In each of the above-described second to fourth aspects, preferably, the selector circuit selects the second position signal when a prescribed time has elapsed since the absolute value of the detected AC voltage reaches the prescribed value or higher.

In the above-described third aspect, preferably, the selector circuit selects the third position signal when the absolute value of the detected AC voltage has reached the prescribed value or higher.

In the above-described third aspect, preferably, the selector circuit selects the third position signal when the prescribed time has elapsed since the absolute value of the detected AC voltage reaches the prescribed value or higher.

In each of the above-described second and third aspects, preferably, the rotor position detection unit further includes a switching circuit for switching whether or not to output the first position signal to the feedback operation unit. The feedback operation unit adjusts a phase of the second position signal based on the first position signal received from the switching circuit. The selector circuit selects the second position signal after the feedback operation unit has adjusted the phase of the second position signal based on the first position signal.

In each of the above-described third and fourth aspects, preferably, the rotor position detection unit further includes a first switching circuit for switching whether or not to output the first position signal to the AC signal generation unit. The AC signal generation unit adjusts a phase of the third position signal based on the first position signal received from the first switching circuit. The selector circuit selects the third position signal after the AC signal generation unit has adjusted the phase of the third position signal based on the first position signal.

In each of the above-described third and fourth aspects, more preferably, the rotor position detection unit further includes a second switching circuit for switching whether or not to output the third position signal to the feedback operation unit. The feedback operation unit adjusts a phase of the second position signal based on the third position signal received from the second switching circuit. The selector circuit selects the second position signal after the feedback operation unit has adjusted the phase of the second position signal based on the third position signal.

Advantageous Effects of Invention

According to the present invention, a synchronous machine can be stably started not only in the standby state but also when it has not returned to the rotational speed in the standby state after stopping of the synchronous machine.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a diagram showing a configuration of a synchronous machine starting device in accordance with a first embodiment of the present invention.

FIG. **2** is a diagram showing a configuration of a rotor position detection unit **11**.

FIG. **3** is a diagram conceptually showing a configuration of a PLL unit **22**.

FIG. **4** is a diagram showing waveforms of a phase signal PH**1** and a position signal POS**1** generated by PLL unit **22**.

FIG. **5** is a diagram showing phase adjustment of phase signal PH**1** by PLL unit **22**.

FIG. **6** is a diagram showing a configuration of a PLL unit **23**.

FIG. **7** is a diagram conceptually showing a configuration of a PLL circuit **34**.

FIG. **8** is a flowchart showing a control procedure by a switching control unit **27** shown in FIG. **2**.

FIG. **9** is a flowchart showing a procedure in the case of starting a synchronous machine from an initial state.

FIG. **10** is a flowchart showing a modification of the control procedure shown in FIG. **8**.

FIG. **11** is a time chart showing operation of a rotor position detection unit.

FIG. **12** is a diagram showing a configuration of a modification of rotor position detection unit **11**.

FIG. **13** is a diagram showing a configuration of an integration unit in a PLL circuit **34** in a modification of rotor position detection unit **11**.

FIG. **14** is a diagram showing a configuration of a rotor position detection unit in accordance with a second embodiment of the present invention.

FIG. **15** is a diagram showing a configuration of an integration unit in PLL circuit **34** in accordance with the second embodiment of the present invention.

FIG. **16** is a diagram showing a configuration of a modification of the integration unit in the synchronous machine starting device in accordance with the second embodiment of the present invention.

FIG. **17** is a diagram showing a configuration of a rotor position detection unit in accordance with a third embodiment of the present invention.

FIG. **18** is a flowchart showing a control procedure by switching control unit **27** shown in FIG. **17**.

FIG. **19** is a flowchart showing a procedure in the case of starting of the synchronous machine from the initial state.

FIG. **20** is a flowchart showing a modification of the control procedure shown in FIG. **18**.

FIG. **21** is a diagram showing a configuration of a rotor position detection unit in accordance with a fourth embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

In the following, embodiments of the present invention will be described with reference to the figures. It is noted that in the figures the same or corresponding parts are denoted by the same reference signs, and a description thereof will not be repeated.

First Embodiment

FIG. **1** is a diagram showing a configuration of a synchronous machine starting device in accordance with a first embodiment of the present invention.

Referring to FIG. **1**, a synchronous machine starting device **101** includes a power conversion unit **71**, an AC voltage detector **8**, an AC current detector **9**, a rotor position detection unit **11**, and an inverter control portion (power conversion control portion) **19**. Power conversion unit **71** includes a converter **1**, an inverter **2**, and a DC reactor **3**. Inverter control portion **19** includes a reference sinusoidal wave operator **12**, a gate pulse generator **13**, and a β command circuit **14**.

A synchronous machine **4** and a motor M are connected with each other via a shaft SH. Synchronous machine **4** is, for example, a synchronous generator or a synchronous motor and has an armature and a rotor. Motor M rotates at a prescribed speed when synchronous machine **4** is on standby. The rotational speed is low, for example, a few rpm. By contrast, the rotational speed in the normal operation is 3000 rpm to 3600 rpm. Therefore, the voltage applied to the armature of synchronous machine **4** at the time of starting is as extremely small as one-thousandth of the steady operation, as described above, and is difficult to detect accurately because the detection voltage by AC voltage detector **8** is often distorted.

Converter **1** is formed of a plurality of elements such as thyristors and converts AC power from an AC power supply e**1** into DC power.

Inverter **2** is formed of a plurality of elements such as thyristors and converts the DC power obtained from converter **1** into AC power for supply to the armature of synchronous machine **4**, thereby driving synchronous machine **4**.

Converter **1** and inverter **2** are connected with each other via DC reactor **3**. The AC side of inverter **2** is connected to the armature of synchronous machine **4**.

AC voltage detector **8** detects three-phase AC voltage supplied to or generated at the armature of synchronous machine **4** (hereinafter referred to as the "armature voltage") and outputs voltage detection values V**1**, V**2**, V**3** to rotor position detection unit **11**.

AC current detector **9** detects the three-phase AC current supplied to the armature of synchronous machine **4** (hereinafter referred to as the "armature current") and outputs current detection values I**1**, I**2**, I**3** to rotor position detection unit **11**.

Rotor position detection unit **11** detects the rotor position (phase) of synchronous machine **4**, based on the detection values received from AC voltage detector **8** and AC current detector **9**, and outputs a rotor position signal POS that indicates the rotor position of synchronous machine **4** to inverter control portion **19**.

Inverter control portion **19** controls inverter **2** based on rotor position signal POS received from rotor position detection unit **11**.

In inverter control portion **19**, reference sinusoidal wave operator **12** outputs a reference sinusoidal wave sin ϕ based on position signal POS received from rotor position detection unit **11**.

β command circuit **14** calculates and outputs a control-advance-angle command value β to gate pulse generator **13**.

Gate pulse generator **13** outputs a gate pulse to each element in inverter **2**, based on reference sinusoidal wave sin ϕ

received form reference sinusoidal wave operator **12** and control lead angle command value β received from β command circuit **14**.

FIG. **2** is a diagram showing a configuration of rotor position detection unit **11**.

Referring to FIG. **2**, rotor position detection unit **11** includes a zero cross detection unit (timing detection unit) **21**, a PLL (Phase Locked Loop) unit (AC signal generation unit) **22**, a PLL unit (feedback operation unit) **23**, a frequency detection unit **24**, a frequency storage unit **25**, a switching control unit **27**, a selector circuit SEL, a switching circuit SW**3**, and a switching circuit (initial frequency selection unit) SW**8**. Selector circuit SEL includes switching circuits SW**1** and SW**2**.

Zero cross detection unit **21** performs zero cross detection of the armature voltage of synchronous machine **4**, based on voltage detection values V**1**, V**2**, V**3** received from AC voltage detector **8**. That is, zero cross detection unit **21** detects the timing at which the value of the armature voltage of synchronous machine **4** passes almost zero volt as a reference level, and outputs a detection signal ZDET indicating the detected timing. Zero cross detection unit **21** also outputs a detection signal SET indicating the phase of the rotor of synchronous machine **4** which is estimated from detection signal ZDET.

Switching circuit SW**3** switches whether or not to output detection signal SET received from zero cross detection unit **21** to PLL unit **22**. Switching by switching circuit SW**3** is controlled by a control signal CTL**2** output from switching control unit **27**.

Frequency detection unit **24** detects a frequency F**1** corresponding to a rotational speed of the rotor of synchronous machine **4** based on detection signal SET received from zero cross detection unit **21** at the time of starting of the synchronous machine starting device. Frequency F**1** can be found as the reciprocal of a zero cross period of each phase, for example.

Frequency storage unit **25** stores a preset frequency F**2**. Frequency F**2** is a frequency corresponding to a predetermined rotational speed of the rotor during standby of synchronous machine **4**.

Switching circuit SW**8** selects either one of frequency F**1** detected by frequency detection unit **24** and frequency F**2** stored in frequency storage unit **25**, and inputs the selected frequency to PLL units **22** and **23** as an initial frequency F**1**. Selection of frequency F**1** or F**2** by switching circuit SW**8** is controlled by a control signal CTL**3** output from switching control unit **27**.

PLL unit **22** outputs a position signal POS**1** that is an AC signal having initial frequency F**1** input from switching circuit SW**8**. PLL unit **22** adjusts the phase of position signal POS**1** based on detection signal SET received from switching circuit SW**3**.

FIG. **3** is a diagram conceptually showing a configuration of PLL unit **22**. FIG. **4** is a diagram showing waveforms of a phase signal PH**1** and position signal POS**1** generated by PLL unit **22**. FIG. **5** is a diagram showing phase adjustment of phase signal PH**1** by PLL unit **22**.

Referring to FIG. **3** to FIG. **5**, PLL unit **22** includes an integrator INT and a position signal generator PGEN. Integrator INT integrates a value corresponding to initial frequency FI input from switching circuit SW**8** and converts the value into a phase θ, which is then output as phase signal PH**1**. Integrator INT resets phase θ to 0° when phase θ attains 360°. That is, phase signal PH**1** is an AC signal whose value changes from 0° to 360°. Integrator INT further corrects phase θ based on an angle such as 30°, 90°, or 150° indicated by detection signal SET received from zero cross detection unit **21**. Position signal generator PGEN generates position signal POS**1** based on the phase indicated by phase signal PH**1** received from integrator INT. As shown in FIG. **4**, for example, position signal generator PGEN converts phase signal PH**1** into a pulse-like AC signal similar to that of the conventional mechanical distributor, and outputs the converted signal as position signal POS**1**. More specifically, for example, position signal POS**1** rises from a logic low level to a logic high level when the phase indicated by phase signal PH**1** changes from 360° to 0°, and falls from a logic high level to a logic low level when the phase indicated by phase signal PH**1** changes to 180°.

In PLL unit **22**, initially, phase θ starts to be increased at any given timing, and then phase θ is adjusted in response to detection signal SET to be synchronized with the armature voltage of synchronous machine **4**. Thus, phase-matching is achieved.

Referring to FIG. **2** again, PLL unit **23** calculates an error of an estimated phase based on the estimated phase indicating the rotor position of synchronous machine **4** (i.e., a phase signal PH**2** described later), an estimated rotational speed of the rotor of synchronous machine **4**, voltage detection values V**1**, V**2**, V**3** received from AC voltage detector **8**, and current detection values I**1**, I**2**, I**3** received from AC current detector **9**, and then updates the estimated phase and the estimated rotational speed based on the calculated phase error. Then, PLL unit **23** outputs position signal POS**2** obtained from the updated estimated phase, and also performs feedback operation of newly calculating an error of the estimated phase based on the updated estimated phase and the updated estimated rotational speed, as well as voltage detection values V**1**, V**2**, V**3** newly received from AC voltage detector **8** and current detection values I**1**, I**2**, I**3** newly received from AC current detector **9**.

FIG. **6** is a diagram showing a configuration of PLL unit **23**.

Referring to FIG. **6**, PLL unit **23** includes three-phase to two-phase conversion circuits **31** and **32**, an induction voltage operation circuit **33**, a PLL circuit **34**, and a position signal generator **35**.

Three-phase to two-phase conversion circuit **31** performs three-phase to two-phase conversion (d-q conversion) of voltage detection values V**1**, V**2**, V**3** received from AC voltage detector **8**, based on a reference phase ϕ.

Three-phase to two-phase conversion circuit **32** performs three-phase to two-phase conversion (d-q conversion) of current detection values I**1**, I**2**, I**3** received from AC current detector **9**, based on reference phase ϕ.

Induction voltage operation circuit **33** calculates induction voltage induced at the armature of synchronous machine **4**, based on voltage values Vd and Vq converted by three-phase to two-phase conversion circuit **31** and current values Id and Iq converted by three-phase to two-phase conversion circuit **32**.

A reference phase synchronized with the rotation of the rotor of synchronous machine **4** is required to perform coordinate transformation, that is, three-phase to two-phase conversion of voltage and current using three-phase to two-phase conversion circuits **31** and **32**. However, in the absence of a position sensor such as a mechanical distributor, this signal cannot be obtained directly.

Then, in the synchronous machine starting device according to the first embodiment of the present invention, three-phase to two-phase conversion circuits **31** and **32** receive an initial value of reference phase ϕ at the time of starting of synchronous machine starting device **101** to perform coordinate transformation.

Then, induction voltage operation circuit **33** calculates induction voltage of the armature on the d-axis (in-phase component)—q-axis (quadrature component) based on the voltage values and current values on the d-q axis converted by three-phase to two-phase conversion circuits **31** and **32**. The calculation of induction voltage requires a rotational speed ω. However, a position sensor is not present, and therefore, frequency FI selected by switching circuit SW**8** as the initial frequency corresponding to an initial value of rotational speed ω of synchronous machine **4** is applied to induction voltage operation circuit **33** at the time of starting of synchronous machine starting device **101**.

When the q-axis component Zq of induction voltage calculated by induction voltage operation circuit **33**, that is, the quadrature component with respect to reference phase ϕ is not zero, the calculation result is shifted with respect to reference phase ϕ. This q-axis component Zq of induction voltage corresponds to an error of the estimated phase of the rotor in synchronous machine **4**. Then, PLL circuit **34** is provided which performs control such that the q-axis component Zq of induction voltage is zero. PLL circuit **34** calculates rotational speed ω, that is, the estimated rotational speed of the rotor of synchronous machine **4** and reference phase ϕ, that is, the estimated phase of the rotor of synchronous machine **4** such that the q-axis component Zq of induction voltage is zero.

FIG. **7** is a diagram conceptually showing a configuration of PLL circuit **34**.

Referring to FIG. **7**, PLL circuit **34** includes a PI controller **36** and an integrator INT. PI controller **36** performs proportional operation and integration operation on the q-axis component Zq of induction voltage output from induction voltage operation circuit **33** in FIG. **6**, and outputs a sum of the results of proportional operation and integration operation. A signal output from PI controller **36** indicates estimated rotational speed ω of the rotor of synchronous machine **4**. Integrator INT integrates estimated rotational speed ω output from PI controller **36** for conversion to phase θ. Integrator INT resets the value of phase θ to 0° when phase θ attains 360°. That is, phase signal PH**2** output from an integrating portion **70** that includes integrator INT in FIG. **7** is an AC signal whose value changes from 0° to 360°. Phase signal PH**2** indicates reference phase ϕ of the rotor.

Referring to FIG. **6** again, reference phase ϕ calculated by PLL circuit **34** is fed back to three-phase to two-phase conversion circuits **31**, **32** and output to position signal generator **35**. Then, position signal generator **35** outputs to selector circuit SEL position signal POS**2** having a pulse-like waveform similar to that of a mechanical distributor. Three-phase to two-phase conversion circuits **31** and **32** afterward perform three-phase to two-phase conversion based on reference phase ϕ from PLL circuit **34**.

Rotational speed ω calculated by PLL circuit **34** is applied to induction voltage operation circuit **33**. Induction voltage operation circuit **33** afterward calculates induction voltage (in-phase component) Zd and induction voltage (quadrature component) Zq, based on rotational speed ω from PLL circuit **34**.

In the synchronous machine starting device according to the first embodiment of the present invention, PLL circuit **34** is configured to calculate rotational speed ω and reference phase ϕ based on the q-axis component Zq of induction voltage only. However, the present invention is not limited thereto. PLL circuit **34** may also be configured to calculate rotational speed ω and reference phase ϕ based on the q-axis component Zq and the d-axis component Zd. Such a configuration enables even more accurate operation.

Referring to FIG. **2** again, selector circuit SEL selects one of detection signal ZDET, position signal POS**1**, and position signal POS**2** and outputs to inverter control portion **19** the selected signal as rotor position signal POS indicating the rotor position of synchronous machine **4**. Selection of detection signal ZDET, position signal POS**1**, and position signal POS**2** by selector circuit SEL is controlled by control signal CTL**1** output from switching control unit **27**.

Switching control unit **27** mainly controls selector circuit SEL, switching circuit SW**3**, and switching circuit SW**8** based on an amplitude of the armature voltage detected by AC voltage detector **8**. Switching control unit **27** then outputs control signals CTL**1**, CTL**2**, CTL**3** for controlling these circuits to selector circuit SEL, switching circuit SW**3**, and switching circuit SW**8**, respectively.

FIG. **8** is a flowchart showing a control procedure by switching control unit **27** shown in FIG. **2**.

Referring to FIGS. **2** and **8**, once the synchronous machine starting device has been started to cause excitation of synchronous machine **4**, an AC voltage corresponding to a current rotational speed of the rotator is generated in an armature winding of synchronous machine **4**. Switching control unit **27** controls selector circuit SEL so that detection signal ZDET from zero cross detection unit **21** is output as rotor position signal POS (Step S**1**). Switching control unit **27** also turns switching circuit SW**3** to an ON state (Step S**2**).

In next Step S**3**, switching control unit **27** determines whether or not an amplitude AMP of the armature voltage at the time of starting of the synchronous machine starting device is a prescribed reference value R**1** or higher. Where amplitude AMP of the armature voltage is reference value R**1** or higher (YES in Step S**3**), switching control unit **27** controls switching circuit SW**8** so that frequency F**1** detected by frequency detection unit **24** is output as initial frequency F**1** (Step S**5**). It can be determined that amplitude AMP is reference value R**1** or higher at the point in time when an absolute value of the armature voltage has reached reference value R**1**. By means of the above-described switching of switching circuits SW**3**, SW**8**, PLL unit **22** outputs position signal POS**1** having almost the same frequency and phase as detection signal ZDET output from zero cross detection unit **21**.

The control procedure after Step S**5** differs depending on whether or not amplitude AMP of the armature voltage is a reference value R**2** (R**2** is set to be a value higher than R**1**). Where amplitude AMP of the armature voltage is lower than reference value R**2** (NO in Step S**6**), switching control unit **27** causes selector circuit SEL to select position signal POS**1** output from PLL unit **22** immediately before the starting of inverter **2** shown in FIG. **1**, and causes the selected position signal POS**1** to be output as rotor position signal POS (Step S**7**). Switching control unit **27** also turns switching circuit SW**3** to an OFF state (Step S**8**). Consequently, PLL unit **22** is not influenced by zero cross detection unit **21** and enters a free-running state, thereby preventing the effect of switching noise immediately after the starting of inverter **2**. Switching control unit **27** causes selector circuit SEL to select and output position signal POS**2** output from PLL unit **23** as rotor position signal POS immediately after the starting of inverter **2**.

On the other hand, where amplitude AMP of the armature voltage is reference value R**2** or higher (YES in Step S**6**), switching noise immediately after the starting of inverter **2** does not become a problem, so that the above-described Steps S**7** and S**8** are not executed. In this case, when, for example, the number of times of zero crossing within a prescribed time has reached a prescribed number (that is, when the frequency corresponding to the current rotational speed of the rotor of the synchronous machine has exceeded a prescribed frequency), switching control unit **27** causes selector circuit SEL to select position signal POS**2** output from PLL unit **23** as rotor position signal POS (Step S**9**).

Where amplitude AMP of the armature voltage is lower than reference value R**1** in Step S**3** (NO in Step S**3**), the synchronous machine starting device is reset (Step S**4**), causing the synchronous machine to be started from the initial state (turning operation). A specific procedure is shown in FIG. **9**.

FIG. **9** is a flowchart showing a procedure in the case of starting of the synchronous machine from the initial state. Where the synchronous machine is started from the initial state (turning operation), the armature voltage detected by AC voltage detector **8** shown in FIG. **2** is a considerably low value and also includes an offset. Since it is thus difficult for frequency detection unit **24** to detect frequency F**1** corresponding to the rotational speed of the rotor, a prescribed frequency F**2** is used as initial frequency F**1**.

Referring to FIGS. **2** and **9**, initially, switching control unit **27** controls selector circuit SEL so that detection signal ZDET from zero cross detection unit **21** is output as rotor position signal POS (Step S**1**). Switching control unit **27** also turns switching circuit SW**3** to the ON state (Step S**2**), and controls switching circuit SW**8** so that prescribed frequency F**2** is output as initial frequency F**1** (Step S**5**A). In this way, PLL unit **22** outputs position signal POS**1** having almost the same frequency and phase as detection signal ZDET output from zero cross detection unit **21**. Then, switching control unit **27** causes selector circuit SEL to select and output position signal POS**1** output from PLL unit **22** as rotor position signal POS immediately before the starting of inverter **2** shown in FIG. **2** (Step S**7**). Switching control unit **27** also turns switching circuit SW**3** to the OFF state (Step S**8**). Consequently, PLL unit **22** is not influenced by zero cross detection unit **21** and enters a free-running state, thereby preventing the effect of switching noise immediately after the starting of inverter **2**. Switching control unit **27** causes selector circuit SEL to select and output position signal POS**2** output from PLL unit **23** as rotor position signal POS immediately after the starting of inverter **2** (Step S**9**).

FIG. **10** is a flowchart showing a modification of the control procedure shown in FIG. **8**. While the control is performed based on amplitude AMP of the armature voltage in Steps S**3**, S**6** shown in FIG. **8**, control is performed based on the number of times of zero crossing within the prescribed time in Steps S**3**A, S**6**A shown in FIG. **10**. In Step S**3**A in FIG. **10**, switching control unit **27** determines whether or not the number of times of zero crossing within the prescribed time is a prescribed reference number of times N**1** or greater, based on detection signal ZDET from zero cross detection unit **21**. Where the number of times of zero crossing within the prescribed time is reference number of times N**1** or greater, the processing proceeds to Step S**5**, and where the number of times of zero crossing within the prescribed time is smaller than reference number of times N**1**, the processing proceeds to Step S**4**. In Step S**6**A in FIG. **10**, switching control unit **27** determines whether or not the number of times of zero crossing within the prescribed time is a prescribed reference number of times N**2** (N**2** is set to a value higher than N**1**) or greater. Where the number of times of zero crossing within the prescribed time is reference number of times N**2** or greater, the processing proceeds to Step S**9**, and where the number of times of zero crossing within the prescribed time is smaller than reference number of times N**1**, the processing proceeds to Step S**7**. Since the procedure in FIG. **10** is otherwise the same as that in FIG. **8**, the same or corresponding steps are denoted by the same reference sings, and a description thereof will not be repeated.

FIG. **11** is a time chart showing the operation of the rotor position detection unit.

Referring to FIGS. **2** and **11**, the control procedure shown in each of FIGS. **8** and **9** will be further described below. In the following description, it is assumed that amplitude AMP of the armature voltage of synchronous machine **4** is lower than reference value R**2**.

Initially, before the starting of inverter **2** (that is, in turning operation during standby, or in inertial rotation immediately after the stopping of the synchronous machine), selector circuit SEL selects detection signal ZDET from zero cross detection unit **21** in accordance with control signal CTL**1** (Step S**1** in FIGS. **8** and **9**). That is, detection signal ZDET is output as rotor position signal POS to reference sinusoidal wave operator **12**.

Switching circuit SW**3** in FIG. **2** is turned ON before the starting of inverter **2** (Step S**2** in FIGS. **8** and **9**), and frequency F**1** or F**2** is selected by switching circuit SW**8** (Step S**5** in FIG. **8** and Step S**5**A in FIG. **9**). PLL unit **22** receives detection signal SET from zero cross detection unit **21** to be synchronized with zero cross detection unit **21** and outputs position signal POS**1** having almost the same frequency and phase as detection signal ZDET from zero cross detection unit **21**.

Then, at a timing T**1** immediately before a timing T**2** at which inverter **2** is started, selector circuit SEL selects position signal POS**1** from PLL unit **22** in accordance with control signal CTL**1** (Step S**7** in FIGS. **8** and **9**). That is, position signal POS**1** is output as rotor position signal POS to reference sinusoidal wave operator **12**.

At timing T**1**, switching circuit SW**3** is turned OFF in accordance with control signal CTL**2** (Step S**8** in FIGS. **8** and **9**), so that PLL unit **22** is not influenced by zero cross detection unit **21** and enters a free-running state.

It is noted that that the armature voltage of synchronous machine **4** is very small at the time of starting of synchronous machine **4**, particularly where the rotor is rotating at an extremely low speed during turning operation. Therefore, immediately after starting of inverter **2**, zero cross detection unit **21** is susceptible to switching noise from inverter **2**. More specifically, zero cross detection unit **21** erroneously detects a zero cross point and outputs an erroneous detection signal ZDET as indicated by NZ in FIG. **11**.

However, in the synchronous machine starting device in accordance with the first embodiment of the present invention, position signal POS**1** from PLL unit **22** is selected at timing T**1** and PLL unit **22** is set in a free-running state, thereby preventing the effect of switching noise from inverter **2**. Before timing T**1**, switching circuit SW**3** is turned ON to achieve synchronization between PLL unit **22** and zero cross detection unit **21**, so that position signal POS**1** in the free-running state can be almost matched in phase with the armature voltage of synchronous machine **4**.

In place of the above-described configuration, selector circuit SEL may be configured to select position signal POS**1** from PLL unit **22** at a timing T**1** when the absolute value of the armature voltage of synchronous machine **4** becomes higher than the prescribed value. Accordingly, PLL unit **22** can be synchronized with zero cross detection unit **21** in a state in which the amplitude of the armature voltage of synchronous machine **4** has become sufficiently high to perform zero cross detection, after the excitation of synchronous machine **4**.

Immediately after the starting, the rotational speed of synchronous machine **4** is low, and therefore, the period of the armature voltage of synchronous machine **4** may be long. Thus, selector circuit SEL may be configured to select position signal POS**1** from PLL unit **22** at a timing T**1** when the prescribed time has elapsed since the absolute value of the armature voltage of synchronous machine **4** becomes higher than the prescribed value. The prescribed time is set such that zero cross detection can be performed accurately. Accordingly, the armature voltage of synchronous machine **4** can be detected more accurately.

Then, at a timing T**3** when a prescribed time has elapsed from timing T**2** when inverter **2** is started, selector circuit SEL selects position signal POS**2** from PLL unit **23** in accordance with control signal CTL**1** (Step S**9** in FIGS. **8** and **9**). More specifically, position signal POS**2** is output as rotor position signal POS to reference sinusoidal wave operator **12**.

At timing T**3** when the prescribed time has elapsed from timing T**2** at which inverter **2** is started, the amplitude of the armature voltage of synchronous machine **4** is larger than that at the time of starting. Therefore, the effect of switching noise from inverter **2** almost disappears, so that the rotor position can be estimated more accurately using the armature voltage and armature current of synchronous machine **4**, and synchronous machine **4** can be rotated stably.

In place of the above-described configuration, selector circuit SEL may be configured to select position signal POS**2** from PLL unit **23** at a timing T**3** when the absolute value of the armature voltage of synchronous machine **4** exceeds the prescribed value, after timing T**2** at which inverter **2** is started.

Selector circuit SEL may be configured to select position signal POS**2** from PLL unit **23** at a timing T**3** when the prescribed time has elapsed since the absolute value of the armature voltage of synchronous machine **4** exceeds the prescribed value, after timing T**2** at which inverter **2** is started.

Alternatively, selector circuit SEL may be configured to select position signal POS**2** from PLL unit **23** at a timing T**3** when the number of times of zero crossing within the prescribed time obtained by zero cross detection unit **21** has reached the prescribed number (that is, when the frequency corresponding to the current rotational speed of the synchronous machine has exceeded the prescribed frequency), after timing T**2** at which inverter **2** is started.

Here, the function of rotor position detection unit **11** is implemented by software. For example, the function of rotor position detection unit **11** is built in, for example, a DSP (Digital Signal Processor) which performs a variety of control in synchronous machine starting device **101**. This reduces the manufacturing costs.

In addition, this eliminates the time and effort of mounting a distributor at a place where synchronous machine **4** and motor M are installed.

In the synchronous machine starting device in accordance with the first embodiment of the present invention, rotor position detection unit **11** is configured to include zero cross detection unit **21**, PLL unit **22**, and PLL unit **23**. However, the present invention is not limited thereto. Even if rotor position detection unit **11** does not include PLL unit **22**, that is, it is configured to select, at the time of starting of synchronous machine **4**, detection signal ZDET from zero cross detection unit **21** and position signal POS**2** from PLL unit **23** in this order as rotor position signal POS, the armature voltage of synchronous machine **4** can be detected with high accuracy at the time of starting of synchronous machine **4**, so that synchronous machine **4** can be started stably.

Even where rotor position detection unit **11** does not include PLL unit **22**, timing T**3** can be set to one of the timing when the prescribed time has elapsed from timing T**2**, the timing when the absolute value of the armature voltage of synchronous machine **4** exceeds the prescribed value after timing T**2**, and the timing when the prescribed time has elapsed since the absolute value of the armature voltage of synchronous machine **4** exceeds the prescribed value after timing T**2**. Timing T**3** can also be set to a timing after timing T**2** when the number of times of zero crossing within the prescribed time obtained by zero cross detection unit **21** has reached the prescribed number (that is, when the frequency corresponding to the current rotational speed of the synchronous machine has exceeded the prescribed frequency).

FIG. **12** is a diagram showing a configuration of a modification of rotor position detection unit **11**.

Referring to FIG. **12**, a rotor position detection unit **81** includes a zero cross detection unit (timing detection unit) **21**, a PLL unit (AC signal generation unit) **22**, a PLL unit (feedback operation unit) **23**, a frequency detection unit **24**, a frequency storage unit **25**, a switching control unit **27**, a selector circuit SEL, a switching circuit SW**3**, and a switching circuit (initial frequency selection unit) SW**8**. Selector circuit SEL includes switching circuits SW**1** and SW**2**.

As described using FIG. **8**, where amplitude AMP of the armature voltage is reference value R**2** or larger at the time of starting of the synchronous machine starting device (YES in Step S**6** in FIG. **8**), the detection voltage detected by AC voltage detector **8** is less susceptible to switching noise immediately after the starting of inverter **2**. In this case, selector circuit SEL may omit position signal POS**1** from PLL unit **22** and directly switch detection signal ZDET from zero cross detection unit **21** to position signal POS**2** from PLL unit **23** (Step S**9** in FIG. **8**).

Where selector circuit SEL directly switches detection signal ZDET to position signal POS**2** as in this case, position signal POS**2** needs to be synchronized early with the armature voltage. Thus, switching circuit SW**3** shown in FIG. **12** switches whether or not to output detection signal SET received from zero cross detection unit **21** to PLL units **22** and **23**.

PLL unit **23** adjusts the phase of position signal POS**2** based on detection signal SET received from switching circuit SW**3**.

FIG. **13** is a diagram showing a configuration of an integration unit **72** in PLL circuit **34** in a modification of rotor position detection unit **11**.

Referring to FIG. **13**, PLL circuit **34** includes integration unit **72** in place of integration unit **70** shown in FIG. **7**. Integration unit **72** has a similar configuration to that of PLL unit **22** shown in FIG. **3**. More specifically, integrator INT integrates and converts rotational speed ω calculated by PI controller **36** shown in FIG. **7** into phase θ, which is then output as reference phase ϕ, that is, phase signal PH**2**. Integrator INT resets phase θ to 0° when phase θ attains 360°. Integrator INT further corrects phase θ based on an angle such as 30°, 90°, or 150° indicated by detection signal SET received from zero cross detection unit **21**.

In integration unit **72**, initially, phase θ starts to be increased at any given timing, and then phase θ is adjusted in response to detection signal SET to be synchronized with the armature voltage of synchronous machine **4**, thus achieving phase-matching.

Referring to FIG. **12** again, selector circuit SEL selects detection signal ZDET, and thereafter selects position signal POS**2** after PLL unit **23** adjusts the phase of position signal POS**2** based on detection signal SET.

With the above-described configuration of integration unit **72**, in rotor position detection unit **81**, after detection signal

ZDET is switched to position signal POS2, position signal POS2 can be synchronized early with the armature voltage of synchronous machine **4**.

In the synchronous machine starting device in accordance with the first embodiment of the present invention, power conversion portion **71** is configured to include converter **1**, inverter **2**, and DC reactor **3**. However, the present invention is not limited thereto. Power conversion portion **71** may be, for example, a matrix converter, in place of converter **1**, inverter **2**, and DC reactor **3**, as long as it is configured to include any circuit that converts supplied power into AC power and supply the AC power to the armature of synchronous motor **4**.

Another embodiment of the present invention will now be described using the drawings. It is noted that the same or corresponding parts in the figures are denoted by the same reference signs, and a description thereof will not be repeated.

Second Embodiment

The present embodiment relates to a synchronous machine starting device in which the function of adjusting the initial phase of position signal POS2 is changed as compared with the synchronous machine starting device in accordance with the first embodiment. The description other than that given below is similar to that of the synchronous machine starting device in accordance with the first embodiment of the present invention.

FIG. **14** is a diagram showing a configuration of a rotor position detection unit in accordance with the second embodiment of the invention.

Referring to FIG. **14**, a rotor position detection unit **82** differs from rotor position detection unit **11** in accordance with the first embodiment of the invention in that it further includes a switching circuit SW**4**.

Switching circuit SW**4** switches whether or not to output phase signal PH**1** received from PLL unit **22** to PLL unit **23**.

PLL unit **23** adjusts the phase of position signal POS**2** based on phase signal PH**1** received from switching circuit SW**4**.

For example, selector circuit SEL selects position signal POS**1** in accordance with control signal CTL**1**, and thereafter selects position signal POS**2** after PLL unit **23** adjusts the phase of position signal POS**2** based on phase signal PH**1**.

FIG. **15** is a diagram showing a configuration of an integration unit in PLL circuit **34** in accordance with the second embodiment of the invention.

Referring to FIG. **15**, PLL circuit **34** includes an integration unit **73** in place of integration unit **70** shown in FIG. **70**. Integration unit **73** has a similar configuration to that of PLL unit **22** shown in FIG. **3**. More specifically, integrator INT integrates and converts rotational speed ω calculated by PI controller **36** shown in FIG. **7** into phase θ, which is then output as reference phase ϕ, that is, phase signal PH**2**. Integrator INT resets phase θ to 0° when phase θ attains 360°. Integrator INT also corrects phase θ based on the angle indicated by phase signal PH**1** received from PLL unit **22**.

In integration unit **73**, initially, phase θ starts to be increased at any given timing, and then phase θ is adjusted in response to phase signal PH**1** to be synchronized with the armature voltage of synchronous machine **4**. Thus, phase-matching is achieved.

Now, phase signal PH**2** is generated based on voltage detection values V**1**, V**2**, V**3** received from AC voltage detector **8** and current detection values I**1**, I**2**, I**3** received from AC current detector **9**. At timing T**3** when a prescribed time has elapsed since timing T**2** at which inverter **2** is started, the selection by selector circuit SEL is switched from position signal POS**1** to position signal POS**2**. This timing T**3** is in a transition period before the amplitude of the armature voltage of synchronous machine **4** becomes large enough. Therefore, if integration unit **73** is operated at a given timing, it may take time for position signal POS**2** to be synchronized with the armature voltage of synchronous machine **4**.

However, in the synchronous machine starting device in accordance with the second embodiment of the present invention, the initial value of phase signal PH**2** is matched with phase signal PH**1**, so that the estimation of the rotor position of synchronous machine **4** by PLL unit **23** can be started from the phase that is almost matched with the armature voltage of synchronous machine **4**. That is, after position signal POS**1** is switched to position signal POS**2**, position signal POS**2** can be synchronized early with the armature voltage of synchronous machine **4**.

FIG. **16** is a diagram showing a configuration of a modification of the integration unit in the synchronous machine starting device in accordance with the second embodiment of the invention.

Referring to FIG. **16**, an integration unit **74** includes integrator INT and switching circuits SW**5**, SW**6**, SW**7**. Integration unit **74** is shared by PLL units **22** and **23**.

More specifically, switching circuit SW**5** switches whether to apply frequency F**1** selected by switching circuit SW**8** shown in FIG. **14** to integrator INT or apply rotational speed ω calculated by PI controller **36** shown in FIG. **7** to integrator INT.

Switching circuit SW**6** switches whether or not to apply detection signal SET received from zero cross detection unit **21** to integrator INT.

Switching circuit SW**7** switches whether to output phase θ from integrator INT as phase signal PH**1** to the position signal generator or to output as phase signal PH**2** to the position signal generator.

Integration unit **74** has a similar configuration to that of PLL unit **22** shown in FIG. **3**. More specifically, integrator NT integrates and converts frequency F**1** or rotational speed ω applied from switching circuit SW**5** into phase θ for output. Integrator INT resets phase θ to 0° when phase θ attains 360°. Integrator INT further corrects phase θ based on an angle such as 30°, 90°, or 150° indicated by detection signal SET received from zero cross detection unit **21**.

In integration unit **74**, initially, phase θ starts to be increased at any given timing, and then phase θ is adjusted in response to detection signal SET to be synchronized with the armature voltage of synchronous machine **4**. Thus, phase-matching is achieved.

The operation of integration unit **74** will now be described.

Initially, when selector circuit SEL selects position signal POS**1** from PLL unit **22** in accordance with control signal CTL**1**, switching circuits SW**5**, SW**6**, SW**7** are switched to the terminal a side. More specifically, switching circuit SW**5** applies frequency F**1** to integrator INT, switching circuit SW**6** applies detection signal SET received from zero cross detection portion **21** to integrator INT, and switching circuit SW**7** outputs phase θ from integrator INT as phase signal PH**1** to the position signal generator.

Then, when selector circuit SEL selects position signal POS**2** from PLL unit **23** in accordance with control signal CTL**1**, simultaneously, switching circuits SW**5**, SW**7** are switched to the terminal b side, and switching circuit SW**6** is opened. More specifically, switching circuit SW**5** applies rotational speed ω calculated by P**1** controller **36** to integrator INT, switching circuit SW**6** does not apply detection signal SET received from zero cross detection unit **21** to integrator

INT, and switching circuit SW7 outputs phase θ from integrator INT as phase signal PH2 to the position signal generator.

In this manner, integration portion **74** can be used to share the integration unit between PLL units **22** and **23**, thereby achieving size reduction. As compared with rotor position detection unit **82** shown in FIG. **14**, the passing of phase signal PH1 between PLL units **22** and **23** is unnecessary. That is, integrator INT can perform the integration operation, taking over the integration result as obtained immediately before timing T3 at which the selection by selector circuit SEL is switched from position signal POS1 to position signal POS2. This can simplify the circuit configuration.

Other configuration and operation are similar to the synchronous machine starting device in accordance with the first embodiment, and therefore, a detailed description thereof will not be repeated here.

Another embodiment of the present invention will now be described using the drawings. It is noted that in the figures the same or corresponding parts are denoted by the same reference signs, and a description thereof will not be repeated.

Third Embodiment

The present embodiment relates to a synchronous machine starting device that differs from the synchronous machine starting device in accordance with the first embodiment in that detection signal ZDET is not selected as rotor position signal POS. The description other than that given below is similar to that of the synchronous machine starting device in accordance with the first embodiment of the present invention.

FIG. **17** is a diagram showing a configuration of a rotor position detection unit in accordance with the third embodiment of the invention.

Referring to FIG. **17**, a rotor position detection unit **83** differs from rotor position detection unit **11** in accordance with the first embodiment of the invention in that selector circuit SEL does not include switching circuit SW**1**.

Selector circuit SEL selects one of position signal POS**1** and position signal POS**2** and outputs the selected signal as rotor position signal POS that indicates the rotor position of synchronous machine **4** to inverter control unit **19**.

FIG. **18** is a flowchart showing a control procedure by switching control unit **27** shown in FIG. **17**.

Referring to FIGS. **17** and **18**, once the synchronous machine starting device has been started to cause excitation of synchronous machine **4**, a voltage corresponding to the current rotational speed of the rotator is generated in the armature winding of synchronous machine **4**. Switching control unit **27** also turns switching circuit SW**3** to the ON state (Step S2).

In next Step S3, switching control unit **27** determines whether or not amplitude AMP of the armature voltage at the time of starting of the synchronous machine starting device is a prescribed reference value R**1** or higher. Where amplitude AMP of the armature voltage is reference value R**1** or higher (YES in Step S3), switching control unit **27** controls switching circuit SW**8** so that frequency F**1** detected by frequency detection unit **24** is output as initial frequency F**1** (Step S5). By means of the switching between switching circuits SW3, SW**8** described above, PLL unit **22** outputs position signal POS**1** having almost the same frequency and phase as detection signal ZDET output from zero cross detection unit **21**.

Then, switching control unit **27** causes selector circuit SEL to output position signal POS**1** output from PLL unit **22** as rotor position signal POS immediately before the starting of inverter **2** shown in FIG. **1** (Step S7). Switching control unit **27** also turns switching circuit SW**3** to the OFF state (Step S**8**). Consequently, PLL unit **22** is not influenced by zero cross detection unit **21** and enters a free-running state. Switching control unit **27** causes selector circuit SEL to output position signal POS**2** output from PLL unit **23** as rotor position signal POS immediately after the starting of inverter **2** (Step S**9**).

On the other hand, in the case of NO in Step S**3** (that is, where amplitude AMP of the armature voltage is lower than reference value R**1**), the synchronous machine starting device is reset (Step S**4**), causing the synchronous machine to be started from the initial state (turning operation). A specific procedure is shown in FIG. **19**.

FIG. **19** is a flowchart showing a procedure in the case of starting of the synchronous machine from the initial state.

Referring to FIGS. **17** and **19**, switching control unit **27** initially turns switching circuit SW**3** to the ON state (Step S2), and controls switching circuit SW**8** so that prescribed frequency F**2** is output as initial frequency F**1** (Step S**5**A). In this way, PLL unit **22** outputs position signal POS**1** having almost the same frequency and phase as detection signal ZDET output from zero cross detection unit **21**. Then, switching control unit **27** causes selector circuit SEL to select and output position signal POS**1** output from PLL unit **22** as rotor position signal POS immediately before the starting of inverter **2** shown in FIG. **1** (Step S7). Switching control unit **27** also turns switching circuit SW**3** to the OFF state (Step S**8**). Consequently, PLL unit **22** is not influenced by zero cross detection unit **21** and enters a free-running state, thereby preventing the effect of switching noise immediately after the starting of inverter **2**. Switching control unit **27** causes selector circuit SEL to select and output position signal POS**2** output from PLL unit **23** as rotor position signal POS immediately after the starting of inverter **2** (Step S9).

FIG. **20** is a flowchart showing a modification of the control procedure shown in FIG. **18**. While the control is performed based on amplitude AMP of the armature voltage in Step S3 shown in FIG. **18**, control is performed based on the number of times of zero crossing within the prescribed time in Step S3A shown in FIG. **20**. In Step S3A in FIG. **20**, switching control unit **27** determines whether or not the number of times of zero crossing within the prescribed time is a prescribed reference number of times N**1** or greater, based on detection signal ZDET from zero cross detection unit **21**. Where the number of times of zero crossing within the prescribed time is reference number of times N**1** or greater, the processing proceeds to Step S**5**, and where the number of times of zero crossing within the prescribed time is smaller than reference number of times N**1**, the processing proceeds to Step S**4**. Since the procedure in FIG. **20** is otherwise the same as that in FIG. **18**, the same or corresponding steps are denoted by the same reference numerals, and a description thereof will not be repeated.

Referring to FIG. **11** again, the control procedure shown in each of FIGS. **18** and **19** will be further described.

Before the starting of inverter **2** (that is, in turning operation during standby, or in inertial rotation immediately after the stopping of the synchronous machine), selector circuit SEL initially selects position signal POS**1** from PLL unit **22** in accordance with control signal CTL**1** (Step S7 in FIGS. **18** and **19**). That is, position signal POS**1** is output as rotor position signal POS to reference sinusoidal wave operator **12**.

Switching circuit SW3 is turned ON before the starting of inverter **2** (Step S2 in FIGS. **18** and **19**), and frequency F**1** or F2 is selected by switching circuit SW**8** (Step S**5** in FIG. **18** and Step **5**A in FIG. **19**). PLL unit **22** receives detection signal SET from zero cross detection unit **21** to be synchronized with zero cross detection unit **21** and outputs position signal POS**1** having almost the same frequency and phase as detection signal ZDET from zero cross detection unit **21**.

Then, at timing T**1** immediately before timing T**2** at which inverter **2** is started, switching circuit SW**3** is turned OFF in accordance with control signal CTL**2** (Step S**8** in FIGS. **18** and **19**). Therefore, PLL unit **22** is not influenced by zero cross detection unit **21** and enters a free-running state.

It is noted that that the armature voltage of synchronous machine **4** is very small at the time of starting of synchronous machine **4**, particularly where the rotor is rotating at an extremely low speed during turning operation. Therefore, immediately after starting of inverter **2**, zero cross detection unit **21** is susceptible to switching noise from inverter **2**. More specifically, zero cross detection unit **21** erroneously detects a zero cross point and generates an erroneous detection signal ZDET as shown by NZ in FIG. **11**, thereby to output an erroneous detection signal SET.

However, the synchronous machine starting device in accordance with the third embodiment of the invention is configured to bring PLL unit **22** into a free-running state at timing T**1**, thereby preventing the effect of switching noise from inverter **2**. Before timing T**1**, switching circuit SW**3** is turned ON to achieve synchronization between PLL unit **22** and zero cross detection unit **21**, so that position signal POS**1** in the free-running state can be almost matched in phase with the armature voltage of synchronous machine **4**.

In place of the above-described configuration, rotor position detection unit **83** may be configured to bring PLL unit **22** into a free-running state at timing T**1** when the absolute value of the armature voltage of synchronous machine **4** becomes higher than the prescribed value. Accordingly, PLL unit **22** can be synchronized with zero cross detection unit **21** in a state in which the amplitude of the armature voltage of synchronous machine **4** has become sufficiently high to perform zero cross detection, after the excitation of synchronous machine **4**.

Immediately after the starting, the rotational speed of synchronous machine **4** is low, and therefore, the period of the armature voltage of synchronous machine **4** may be long. Thus, rotor position detection unit **83** may be configured to bring PLL unit **22** into a free-running state at timing T**1** when the prescribed time has elapsed since the absolute value of the armature voltage of synchronous machine **4** becomes higher than the prescribed value. The prescribed time is set such that zero cross detection can be performed accurately. Accordingly, the armature voltage of synchronous machine **4** can be detected more accurately.

Then, at a timing T**3** after a prescribed time has elapsed from timing T**2** when inverter **2** is started, selector circuit SEL selects position signal POS**2** from PLL unit **23** in accordance with control signal CTL**1** (Step S**9** in FIGS. **18** and **19**). More specifically, position signal POS**2** is output as rotor position signal POS to reference sinusoidal wave operator **12**.

At timing T**3** when the prescribed time has elapsed from timing T**2** at which inverter **2** is started, the amplitude of the armature voltage of synchronous machine **4** is larger than that at the time of starting. Therefore, the effect of switching noise from inverter **2** almost disappears, so that the rotor position can be estimated more accurately using the armature voltage and armature current of synchronous machine **4**, and synchronous machine **4** can be rotated stably.

In place of the above-described configuration, selector circuit SEL may be configured to select position signal POS**2** from PLL unit **23** at timing T**3** when the absolute value of the armature voltage of synchronous machine **4** exceeds the prescribed value, after timing T**2** at which inverter **2** is started.

Selector circuit SEL may be configured to select position signal POS**2** from PLL unit **23** at timing T**3** when the prescribed time has elapsed since the absolute value of the armature voltage of synchronous machine **4** exceeds the prescribed value, after timing T**2** at which inverter **2** is started.

Alternatively, selector circuit SEL may be configured to select position signal POS**2** from PLL unit **23** at timing T**3** when the number of times of zero crossing within the prescribed time obtained by zero cross detection unit **21** has reached the prescribed number (that is, when the frequency corresponding to the current rotational speed of the synchronous machine has exceeded the prescribed frequency), after timing T**2** at which inverter **2** is started.

In the synchronous machine starting device in accordance with the third embodiment of the invention, PLL unit **22** adjusts the phase of position signal POS**1** based on detection signal SET received from zero cross detection unit **21**. Accordingly, even if detection signal ZDET from zero cross detection unit **21** is not selected as rotor position signal POS, the rotor position of synchronous machine **4** can be detected well by selecting position signal POS**1** as rotor position signal POS. In this configuration, selector circuit SEL does not include switching circuit SW**1**, so that size reduction of the synchronous machine starting device can be achieved.

Other configuration and operation are similar to the synchronous machine starting device in accordance with the first embodiment, and therefore, a detailed description thereof will not be repeated here.

Another embodiment of the present invention will now be described using the drawings. It is noted that in the figures the same or corresponding parts are denoted by the same reference signs, and a description thereof will not be repeated.

Fourth Embodiment

The present embodiment relates to a synchronous machine starting device in which the function of adjusting the initial phase of position signal POS**2** is changed as compared with the synchronous machine starting device in accordance with the third embodiment. The description other than that given below is similar to that of the synchronous machine starting device in accordance with the third embodiment of the present invention.

FIG. **21** is a diagram showing a configuration of a rotor position detection unit in accordance with the fourth embodiment of the invention.

Referring to FIG. **21**, a rotor position detection unit **84** differs from rotor position detection unit **83** in accordance with the third embodiment of the invention in that it further includes switching circuit SW**4**.

Switching circuit SW**4** switches whether or not to output phase signal PH**1** received from PLL unit **22** to PLL unit **23**.

PLL unit **23** adjusts the phase of position signal POS**2** based on phase signal PH**1** received from switching circuit SW**4**.

For example, selector circuit SEL selects position signal POS**1** in accordance with control signal CTL**1**, and thereafter selects position signal POS**2** after PLL unit **23** adjusts the phase of position signal POS**2** based on phase signal PH**1**.

The configuration and operation of integration units **73** and **74** in PLL circuit **34** of rotor position detection unit **84** is similar to the second embodiment of the invention, and therefore, a detailed description thereof will not be repeated.

Other configuration and operation are similar to the synchronous machine starting device in accordance with the third embodiment, and therefore, a detailed description thereof will not be repeated here.

The embodiments disclosed here should be understood as being illustrative rather than being limitative in all respects. The scope of the present invention is shown not in the above-described description but in the claims, and it is intended that all modifications that come within the meaning and range of equivalence to the claims are embraced here.

REFERENCE SIGNS LIST

1 converter, **2** inverter, **3** DC reactor, **8** AC voltage detector, **9** AC current detector, **11**, **81**, **82**, **83**, **84** rotor position detection unit, **12** reference sinusoidal wave operator, **13** gate pulse generator, **14** β command circuit, **19** inverter control unit (power conversion control unit), **21** zero cross detection unit (timing detection unit), **22** PLL unit (AC signal generation unit), **23** PLL unit (feedback operation unit), **24** frequency detection unit, **25** frequency storage unit, **27** switching control unit, **31**, **32** three-phase to two-phase conversion circuit, **33** induction voltage operation circuit, **34** PLL circuit, **71** power conversion unit, **101** synchronous machine starting device, SEL selector circuit, SW**1**-SW**7** switching circuit, SW**8** switching circuit (initial frequency selection unit), INT integrator, **35** PGEN position signal generator.

The invention claimed is:

1. A synchronous machine starting device comprising:

a power conversion unit for converting supplied power into AC power and supplying the AC power to an armature of a synchronous machine;

an AC voltage detection unit for detecting AC voltage supplied to or generated at the armature of said synchronous machine;

an AC current detection unit for detecting AC current supplied to or generated at the armature of said synchronous machine;

a rotor position detection unit for detecting a rotor position of said synchronous machine, based on said detected AC voltage and AC current; and

a power conversion control portion for controlling said power conversion unit, based on said detected rotor position,

said rotor position detection unit including:

a timing detection unit for outputting a first position signal indicating a timing at which a value of said detected AC voltage passes a prescribed reference level;

a feedback operation unit for calculating an error of an estimated phase based on said estimated phase indicating said rotor position, an estimated rotational speed of the rotor of said synchronous machine, as well as said detected AC voltage and AC current, updating said estimated phase and said estimated rotational speed based on said calculated phase error, and outputting a second position signal indicating said updated estimated phase;

a frequency detection unit for detecting a first frequency corresponding to a rotational speed of the rotor of said synchronous machine at the time of starting of said synchronous machine starting device based on said first position signal, for use as an initial frequency corresponding to an initial value of said estimated rotational speed; and

a selector circuit for selecting said first position signal or a position signal obtained based on said first position signal, outputting the selected signal to said power conversion control portion as a signal indicating the rotor position of said synchronous machine, releasing selection of said first position signal or the position signal obtained based on said first position signal, and thereafter selecting said second position signal for output to said power conversion control portion as a signal indicating the rotor position of said synchronous machine.

2. The synchronous machine starting device according to claim **1**, wherein

said rotor position detection unit further includes:

an initial frequency selection unit for selecting either one of said first frequency and a prescribed second frequency as said initial frequency;

said second frequency is a frequency corresponding to a prescribed rotational speed of said rotor during standby of said synchronous machine;

said initial frequency selection unit selects said first frequency where an absolute value of said detected AC voltage is a prescribed value or higher at the time of starting of said synchronous machine starting device; and

said initial frequency selection unit selects said second frequency where the absolute value of said detected AC voltage does not reach said prescribed value within a prescribed time at the time of starting of said synchronous machine starting device.

3. The synchronous machine starting device according to claim **1**, wherein

said rotor position detection unit further includes an initial frequency selection unit for selecting either one of said first frequency and a prescribed second frequency as said initial frequency,

said second frequency is a frequency corresponding to a predetermined rotational speed of said rotor during standby of said synchronous machine,

said initial frequency selection unit selects said first frequency where the number of times that the value of said detected AC voltage passes said reference level within a prescribed time is a prescribed number or greater at the time of starting of said synchronous machine starting device, and

said initial frequency selection unit selects said second frequency where the number of times that the value of said detected AC voltage passes said reference level within said prescribed time is smaller than said prescribed number at the time of starting of said synchronous machine starting device.

4. The synchronous machine starting device according to claim **1**, wherein

said selector circuit initially selects said first position signal for output to said power conversion control portion, and then selects said second position signal for output to said power conversion control portion.

5. The synchronous machine starting device according to claim **1**, wherein

said rotor position detection unit further includes an AC signal generation unit for outputting a third position signal that is an AC signal having said initial frequency and having a phase adjusted to be synchronized with said first position signal, and said selector circuit selects said first position signal, said third position signal, and said second position signal in this order, for output to said power conversion control portion.

6. The synchronous machine starting device according to claim **1**, wherein

said rotor position detection unit further includes an AC signal generation unit for outputting a third position signal that is an AC signal having said initial frequency and having a phase adjusted to be synchronized with said first position signal, and

said selector circuit initially selects said third position signal for output to said power conversion control portion, and then selects said second position signal for output to said power conversion control portion.

7. The synchronous machine starting device according to claim **1**, wherein

said rotor position detection unit further includes an AC signal generation unit for outputting a third position signal that is an AC signal having said initial frequency and having a phase adjusted to be synchronized with said first position signal,

where an absolute value of said detected AC voltage is a prescribed value or higher at the time of starting of said synchronous machine starting device, said selector circuit initially selects said first position signal for output to said power conversion control portion, and then selects said second position signal for output to said power conversion control portion, and

where the absolute value of said detected AC voltage does not reach said prescribed value within a prescribed time at the time of starting of said synchronous machine starting device, said selector circuit selects said first position signal, said third position signal, and said second position signal in this order, for output to said power conversion control portion.

8. The synchronous machine starting device according to claim **1**, wherein

said rotor position detection unit further includes an AC signal generation unit for outputting a third position signal that is an AC signal having said initial frequency and having a phase adjusted to be synchronized with said first position signal,

where the number of times that the value of said detected AC voltage passes said reference level within a prescribed time is a prescribed number or greater at the time of starting of said synchronous machine starting device, said selector circuit initially selects said first position signal for output to said power conversion control portion, and then selects said second position signal for output to said power conversion control portion, and

where the number of times that the value of said detected AC voltage passes said reference level within said prescribed time is smaller than said prescribed number at the time of starting of said synchronous machine starting device, said selector circuit selects said first position signal, said third position signal, and said second position signal in this order, for output to said power conversion control portion.

9. The synchronous machine starting device according to claim **4**, wherein

said selector circuit selects said second position signal when the number of times that the value of said detected AC voltage passes said reference level within a prescribed time has exceeded a prescribed number.

10. The synchronous machine starting device according to claim **4**, wherein

said selector circuit selects said second position signal when a prescribed time has elapsed since an absolute value of said detected AC voltage reaches a prescribed value or higher.

11. The synchronous machine starting device according to claim **5**, wherein

said selector circuit selects said third position signal when a prescribed time has elapsed since an absolute value of said detected AC voltage reaches a prescribed value or higher.

12. The synchronous machine starting device according to claim **4**, wherein

said rotor position detection unit further includes a switching circuit for switching whether or not to output said first position signal to said feedback operation unit,

said feedback operation unit adjusts a phase of said second position signal based on said first position signal received from said switching circuit, and

said selector circuit selects said second position signal after said feedback operation unit has adjusted the phase of said second position signal based on said first position signal.

13. The synchronous machine starting device according to claim **5**, wherein

said rotor position detection unit further includes a first switching circuit for switching whether or not to output said first position signal to said AC signal generation unit,

said AC signal generation unit adjusts a phase of said third position signal based on said first position signal received from said first switching circuit, and

said selector circuit selects said third position signal after said AC signal generation unit has adjusted the phase of said third position signal based on said first position signal.

14. The synchronous machine starting device according to claim **13**, wherein

said rotor position detection unit further includes a second switching circuit for switching whether or not to output said third position signal to said feedback operation unit,

said feedback operation unit adjusts a phase of said second position signal based on said third position signal received from said second switching circuit, and

said selector circuit selects said second position signal after said feedback operation unit has adjusted the phase of said second position signal based on said third position signal.

15. The synchronous machine starting device according to claim **5**, wherein

said selector circuit selects said second position signal when the number of times that the value of said detected AC voltage passes said reference level within a prescribed time has exceeded a prescribed number.

16. The synchronous machine starting device according to claim **6**, wherein

said selector circuit selects said second position signal when the number of times that the value of said detected AC voltage passes said reference level within a prescribed time has exceeded a prescribed number.

17. The synchronous machine starting device according to claim **5**, wherein

said selector circuit selects said second position signal when a prescribed time has elapsed since an absolute value of said detected AC voltage reaches a prescribed value or higher.

18. The synchronous machine starting device according to claim **6**, wherein

said selector circuit selects said second position signal when a prescribed time has elapsed since an absolute value of said detected AC voltage reaches a prescribed value or higher.

19. The synchronous machine starting device according to claim **6**, wherein

said rotor position detection unit further includes a first switching circuit for switching whether or not to output said first position signal to said AC signal generation unit, said AC signal generation unit adjusts a phase of said third position signal based on said first position signal received from said first switching circuit, and

said selector circuit selects said third position signal after said AC signal generation unit has adjusted the phase of said third position signal based on said first position signal.

20. The synchronous machine starting device according to claim **19**, wherein

said rotor position detection unit further includes a second switching circuit for switching whether or not to output said third position signal to said feedback operation unit,

said feedback operation unit adjusts a phase of said second position signal based on said third position signal received from said second switching circuit, and

said selector circuit selects said second position signal after said feedback operation unit has adjusted the phase of said second position signal based on said third position signal.

* * * * *